



Bolt Shear Impact Test on In-Pavement Light Fixture Bolt Configurations

For	MCB Industries Inc. 310 North Wisconsin Suite E De Pere, WI 54115
P.O. Number	Credit Card
Date Tested	September 8, 2021
Test Personnel	Kate Fanning
Test Documents	Customer Test Plan Environmental Procedure: FAA EB83A Bolt Shear Impact rev1.0

Test Report By:

Kate Fanning
ENV Engineer

Requested By:

Mary Baeten
MCB Industries Inc.

Approved By:

Mark Gabalewicz
Environmental Team Leader
Senior Mechanical Engineer

Elite Electronic Engineering Inc.

1516 CENTRE CIRCLE
DOWNERS GROVE, IL 60515

TEL: 630 - 495 - 9770

FAX: 630 - 495 - 9785

www.elitetest.com

Table of Contents

- 1. Report Revision History 3
- 2. Introduction 4
- 3. Test Documents 4
- 4. Modifications Made to DUT and/or Deviations to the Test Documents During Testing 4
- 5. Summary 4
- 6. Operation States 4
- 6.1. Unpowered 5
- 7. Performance/Monitoring 5
- 8. Acceptance Criteria 5
- 9. Certification 5
- 10. Device Under Test Photographs 6
- 11. Test Sections 12
- 11.1. Bolt Shear Impact 12
- 11.1.1. Requirements: 12
- 11.1.2. Test Procedure: 12
- 11.1.3. Description of Test Apparatus: 14
- 11.1.4. Test Results: 14

**This report shall not be reproduced, except in full,
without the written approval of Elite Electronic Engineering Inc.**

1. REPORT REVISION HISTORY

Revision	Date	Description
-	September 23, 2021	Initial release
A	October 5, 2021 by Kate Fanning	<ul style="list-style-type: none"> - Added "Rev. A" to the report number throughout the report. - Section 2: Removed "(1) 1-5/16"" throughout the "Part Descriptions" column. Added M10 washer to the table. - Section 11.1.2: Updated the "Components" column in the table for Orientation C, D, G, H, and M. <ul style="list-style-type: none"> • Orientation C: Changed "M10 washers" and "M10 GR35 washers" to "M10 washers" and "GR35 washers" • Orientation D: Changed "GR35 and M10 GR35 washers" to "GR55 washers" • Orientation G: Changed "GR35 and M10 GR35 washers" to "GR35 washers" and "M10 washers" • Orientation H: Changed "M10 GR35 washers" to "GR55 washers" • Orientation M: Removed "(1) 1-5/16""

2. INTRODUCTION

This document presents the results of an environmental (ENV) test that was performed on sixteen (16) In-Pavement Light Fixture Bolt Configurations (hereinafter referred to as the Device Under Test (DUT)). The DUTs were identified as follows:

Part Description	S/N
SAE J429 Grade 5 Bolt (uncoated) – 3.00"	A, A1, N
ASTM F593C Bolt (coated with integrated locking washer) – 3.00"	B, C, D, E, E1, G, H, I, I1, O, P, R
ASTM F593C Bolt (coated with integrated locking washer) – 4.00"	M
2-part ramp washers	N/A
HDG (Galvanized) Impact Plate	Red
HDG (Galvanized) Spacers – (1) 3/4"; (1) 1/2"; (1) 1/4"; (1) 1/8"; (2) 1/16"	Red
HDG (Galvanized) Mounting Bar	Red
#21 Impact Plate	Yellow
#21 Spacers – (1) 3/4"; (1) 1/2"; (1) 1/4"; (1) 1/8"; (2) 1/16"	Yellow
#21 Mounting Bar	Yellow
B50 (RCSC Class B Coating) Impact Plate	Green
B50 (RCSC Class B Coating) Spacers – (1) 3/4"; (1) 1/2"; (1) 1/4"; (1) 1/8"; (2) 1/16"	Green
B50 (RCSC Class B Coating) Mounting Bar	Green
GR35 washer	N/A
GR55 washer	N/A
M10 washer	N/A

3. TEST DOCUMENTS

The test was performed in accordance with the Customer Test Plan and the Environmental Procedure: FAA EB83A Bolt Shear Impact rev1.0.

4. MODIFICATIONS MADE TO DUT AND/OR DEVIATIONS TO THE TEST DOCUMENTS DURING TESTING

No modifications were made to the DUTs during the testing. No deviations from the test documents were made during the testing.

5. SUMMARY

The following ENV test was performed, and the results are shown below:

Test Description	Document Section	Test Results	S/N	Date Tested
Bolt Shear Impact	Customer Test Plan and Environmental Procedure: FAA EB83A Bolt Shear Impact rev1.0	See Section 11.1.4	A, A1, B, C, D, E, E1, G, H, I, I1, M, N, O, P, R	09/08/2021

6. OPERATION STATES

The ENV test was performed with the DUTs operating in one or more of the test modes described below.

6.1. Unpowered

The DUTs were unpowered throughout the test.

7. PERFORMANCE/MONITORING

The DUTs were visually monitored and video recorded during testing. A torque wrench was used to measure the breakaway torque of the DUT's bolt following the test.

8. ACCEPTANCE CRITERIA

The DUTs shall withstand the specified shear impact force without breakage or excessive deformation. The DUTs shall have the ability to be fully removed from the fixture after test is complete.

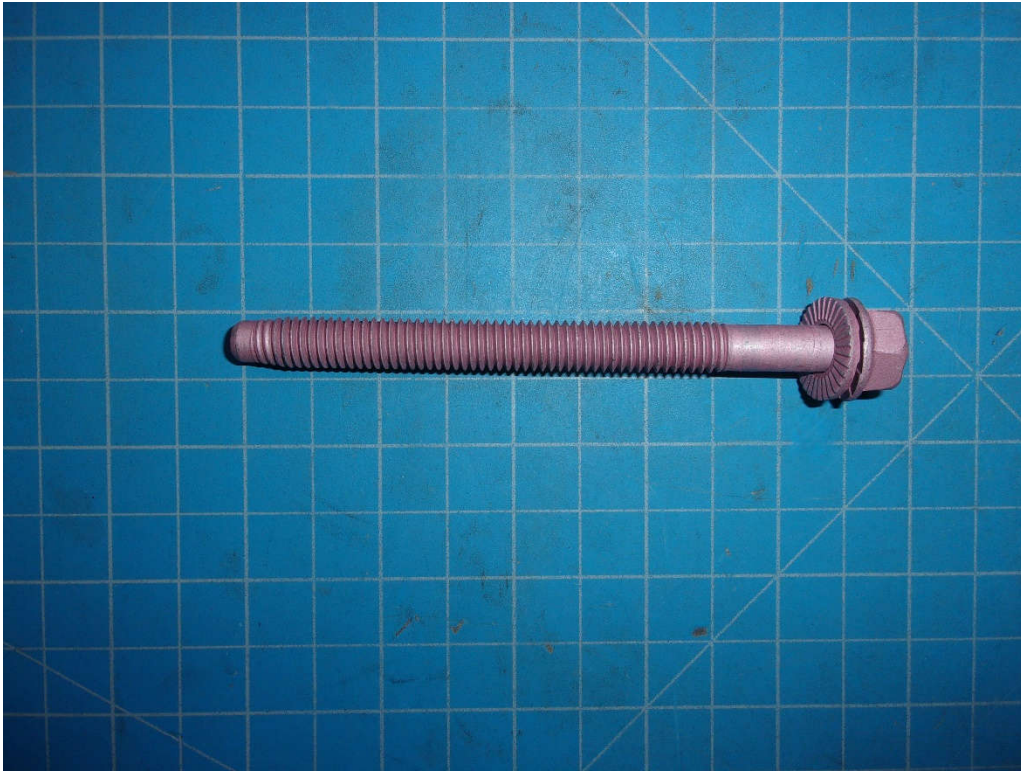
9. CERTIFICATION

Elite Electronic Engineering Incorporated certifies that the information contained in this report was obtained under conditions which meet or exceed those specified in the test specifications, except if noted otherwise. The data presented in this test report pertains to the DUTs at the test date as operated and monitored if required. Any electrical or mechanical modification made to the DUTs subsequent to the specified test date will serve to invalidate the data and void this certification.

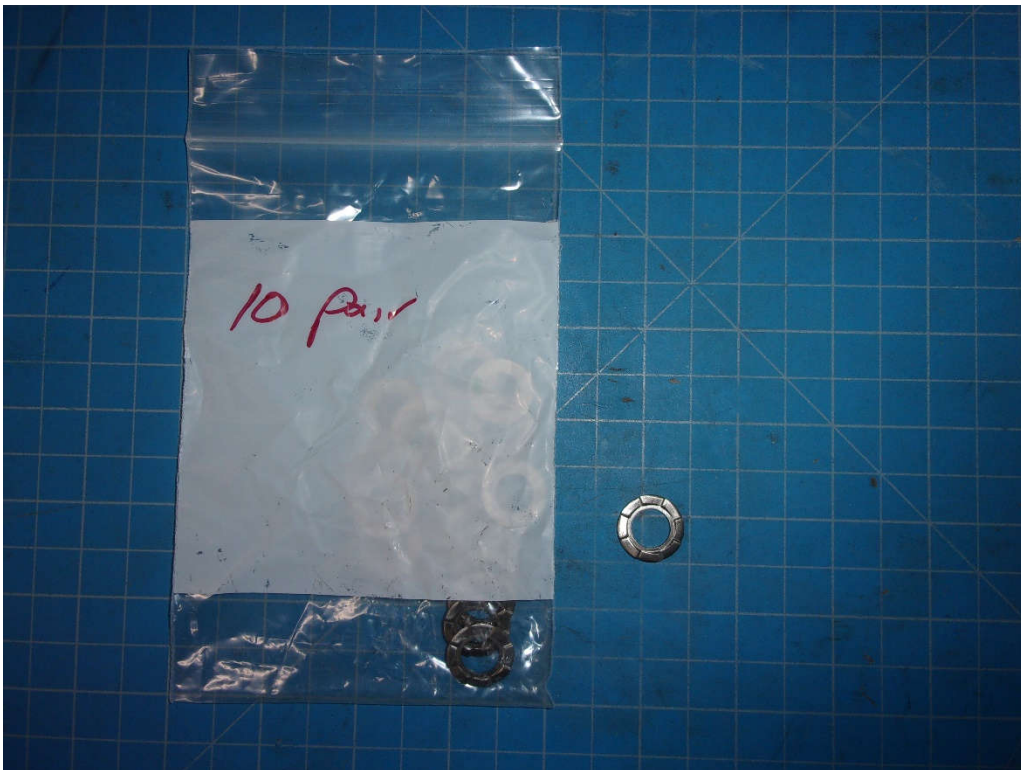
10. DEVICE UNDER TEST PHOTOGRAPHS



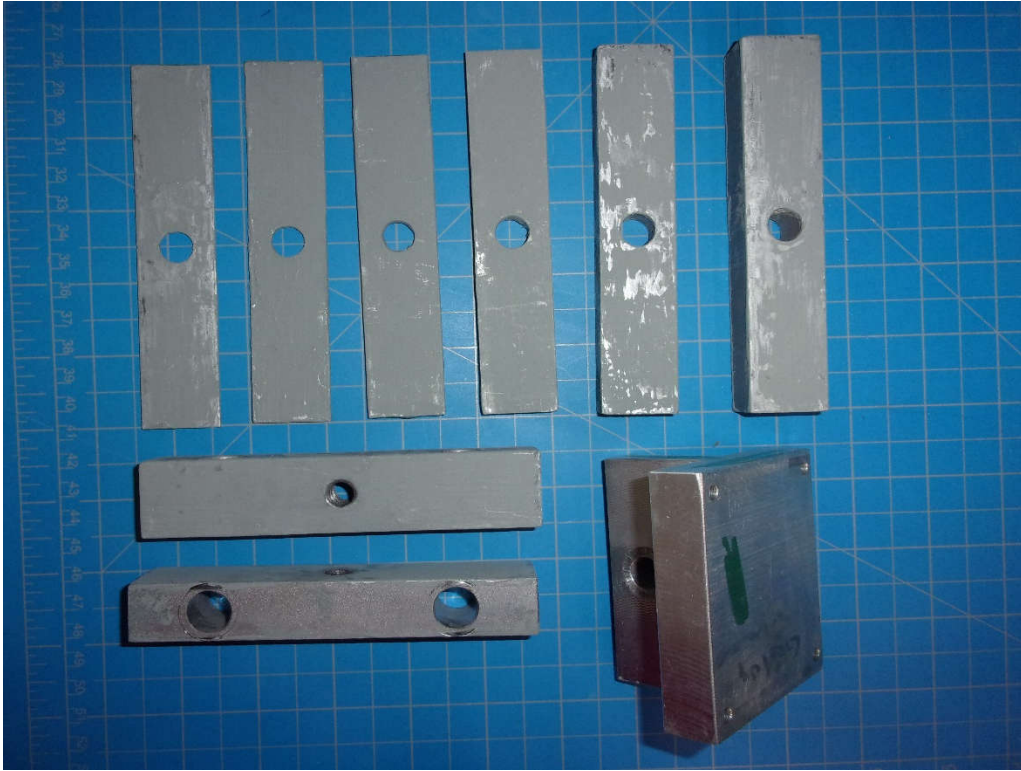
DUT Test Bolts (SAE J429 Grade 5 Bolt – Top and ASTM F593C Bolt – 3.00” – Bottom)



DUT Test Bolt (ASTM F593C Bolt – 4.00")



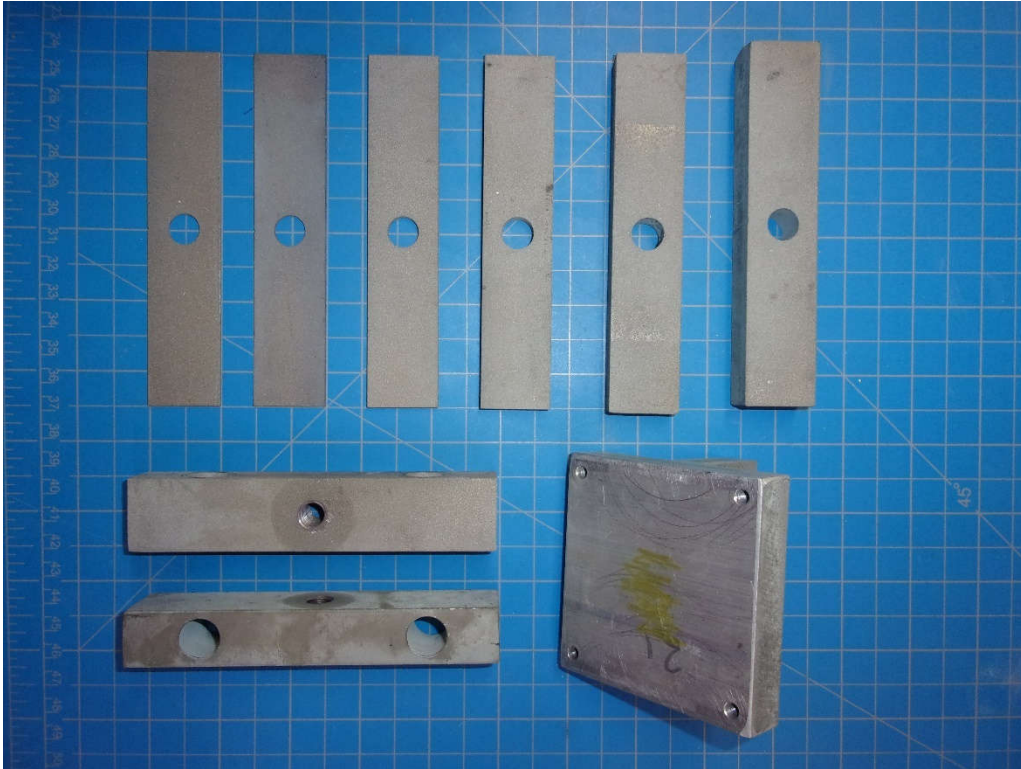
2-part Ramp Washers



B50 (RCSC Class B Coating) Samples:
Spacers – (1) 3/4"; (1) 1/2"; (1) 1/4"; (1) 1/8"; (2) 1/16"
Impact Plate and Mounting Bars



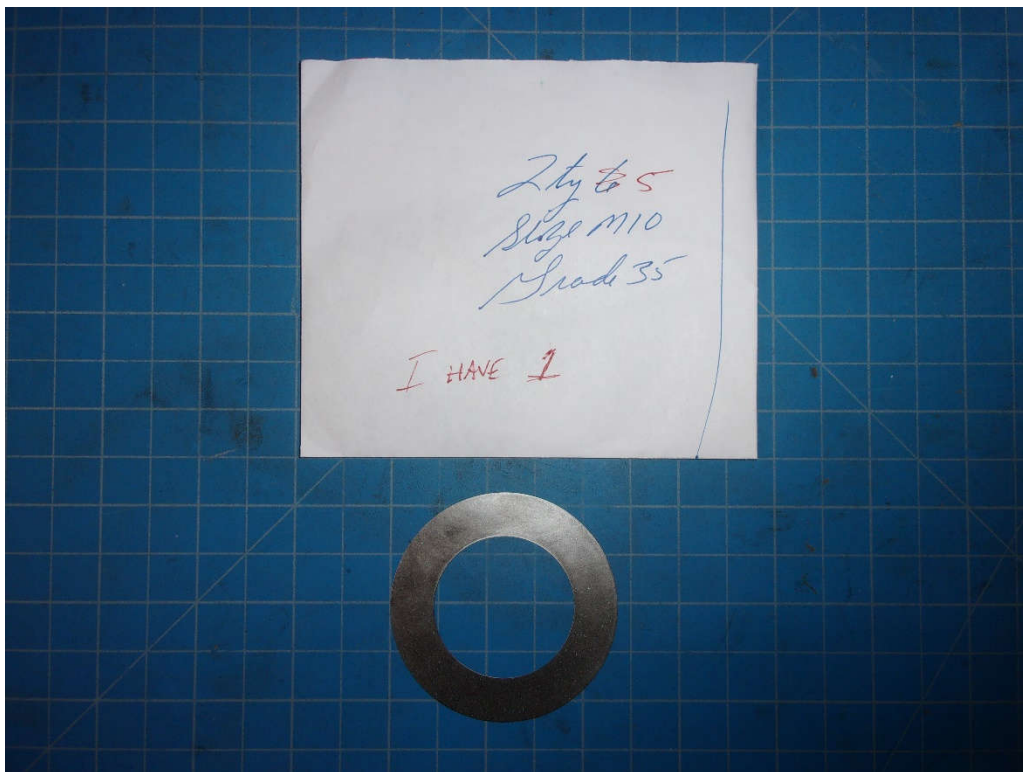
HDG (Galvanized) Samples:
Spacers – (1) 3/4"; (1) 1/2"; (1) 1/4"; (1) 1/8"; (2) 1/16"
Impact Plate and Mounting Bar



#21 Samples:
Spacers – (1) 3/4"; (1) 1/2"; (1) 1/4"; (1) 1/8"; (2) 1/16"
Impact Plate and Mounting Bars



GR55 Washers



GR35 Washer

11. TEST SECTIONS

11.1. Bolt Shear Impact

11.1.1. Requirements:

The DUTs shall withstand the specified shear impact force without breakage or excessive deformation. The DUTs shall have the ability to be fully removed from the fixture after test is complete.

11.1.2. Test Procedure:

The test was conducted in accordance with the Customer Test Plan and the Environmental Procedure: FAA EB83A Bolt Shear Impact rev1.0.

FAA EB83A, Appendix A, specifies the aircraft configuration and assumptions used to determine the shear (maximum traction) force imparted on in-pavement light fixtures by an Airbus A380-800 aircraft. This is the maximum potential shear force present on U.S. airports and was used to set the two target shear impact forces and impact durations for testing:

Description	Total Shear Force (lb)	Shear Force per Bolt (lb)	Target Shear Impact Force (lb)
Maximum Traction Force	19,760	3,293	3,300
Differential Force Required by Bolts	10,620	1,770	1,770

- A380-800 Landing Speed \approx 170 mph = 2992 in/sec
- Time for Tire to Roll Over 12" Light Fixture = $12 / 2992 = 4$ ms
- Target Impact Duration \leq 4 ms

Target bolt torque was specified by MCB Industries, Inc. to achieve the following clamping forces:

Bolt Type	Specified Torque (ft-lb)	Clamping Force (lb)
SAE J429 Grade 5 (uncoated)	62 to 64	4,900
ASTM F593C (coated with integrated locking washer)	42 to 44	3,800

The DUTs consisted of an assembly of washers, spacers, and/or shims in a specific order, referred to as a "stack," and held in place with a 3/8"-16 bolt of a specified length. The DUT stack was then assembled and mounted to the impact tester as specified by MCB Industries, Inc. The DUT impact plate and stack were aligned to be perpendicular to the hammer impact path. Using a torque wrench, the DUT test bolt was tightened to the specified torque. The impact hammer was adjusted as necessary to align with the center of the DUT impact plate. The number of impacts was defined by MCB Industries, Inc.

Several stack orientations were defined by MCB Industries, Inc., to evaluate the performance of different faying surface coatings. The orientations are as follows:

Orientation	Components	Number of Hits	Target Force (lbf)
A	<ul style="list-style-type: none"> • Grade 5 3.00" Bolt • HDG (Galvanized) Impact Plate • HDG (Galvanized) Spacers – (1) 3/4"; (1) 1/2"; (1) 1/16" • HDG (Galvanized) Mounting Bar 	1	3300

A1	<ul style="list-style-type: none"> • Grade 5 3.00" Bolt • HDG (Galvanized) Impact Plate • HDG (Galvanized) Spacers – (1) 3/4"; (1) 1/2"; (1) 1/16" • HDG (Galvanized) Mounting Bar 	3	3300
B	<ul style="list-style-type: none"> • F593C 3.00" Bolt • HDG (Galvanized) Impact Plate • HDG (Galvanized) Spacers – (1) 3/4"; (1) 1/2"; (1) 1/16" • M10 washers • HDG (Galvanized) Mounting Bar 	1	3300
C	<ul style="list-style-type: none"> • F593C 3.00" Bolt • HDG (Galvanized) Impact Plate • HDG (Galvanized) Spacers – (1) 3/4"; (1) 1/2"; (1) 1/16" • GR35 washers • M10 washers • HDG (Galvanized) Mounting Bar 	1	3300
D	<ul style="list-style-type: none"> • F593C 3.00" Bolt • HDG (Galvanized) Impact Plate • HDG (Galvanized) Spacers – (1) 3/4"; (1) 1/2"; (1) 1/16" • GR55 washers • HDG (Galvanized) Mounting Bar 	1	3300
E	<ul style="list-style-type: none"> • F593C 3.00" Bolt • B50 (RCSC Class B Coating) Impact Plate • B50 (RCSC Class B Coating) Spacers – (1) 3/4"; (1) 1/2"; (1) 1/16" • B50 (RCSC Class B Coating) Mounting Bar 	1	3300
E1	<ul style="list-style-type: none"> • F593C 3.00" Bolt • B50 (RCSC Class B Coating) Impact Plate • B50 (RCSC Class B Coating) Spacers – (1) 3/4"; (1) 1/2"; (1) 1/16" • B50 (RCSC Class B Coating) Mounting Bar 	3	3300
G	<ul style="list-style-type: none"> • F593C 3.00" Bolt • B50 (RCSC Class B Coating) Impact Plate • B50 (RCSC Class B Coating) Spacers – (1) 3/4"; (1) 1/2"; (1) 1/16" • GR35 washers • M10 washers • B50 (RCSC Class B Coating) Mounting Bar 	1	3300
H	<ul style="list-style-type: none"> • F593C 3.00" Bolt • B50 (RCSC Class B Coating) Impact Plate • B50 (RCSC Class B Coating) Spacers – (1) 3/4"; (1) 1/2"; (1) 1/16" • GR55 washers • B50 (RCSC Class B Coating) Mounting Bar 	1	3300
I	<ul style="list-style-type: none"> • F593C 3.00" Bolt • #21 Impact Plate • #21 Spacers – (1) 3/4"; (1) 1/2"; (1) 1/16" • #21 Mounting Bar 	1	3300
I1	<ul style="list-style-type: none"> • F593C 3.00" Bolt • #21 Impact Plate • #21 Spacers – (1) 3/4"; (1) 1/2"; (1) 1/16" • #21 Mounting Bar 	3	3300

M	<ul style="list-style-type: none"> • F593C 4.00" Bolt • #21 Impact Plate • #21 Spacers – (1) 3/4"; (1) 1/2"; (1) 1/4"; (1) 1/8"; (2) 1/16" • #21 Mounting Bar 	1	3300
N	<ul style="list-style-type: none"> • Grade 5 3.00" Bolt • HDG (Galvanized) Impact Plate • HDG (Galvanized) Spacers – (1) 3/4"; (1) 1/2"; (1) 1/16" • HDG (Galvanized) Mounting Bar 	1	1770
O	<ul style="list-style-type: none"> • F593C 3.00" Bolt • B50 (RCSC Class B Coating) Impact Plate • B50 (RCSC Class B Coating) Spacers – (1) 3/4"; (1) 1/2"; (1) 1/16" • B50 (RCSC Class B Coating) Mounting Bar 	1	1770
P	<ul style="list-style-type: none"> • F593C 3.00" Bolt • #21 Impact Plate • #21 Spacers – (1) 3/4"; (1) 1/2"; (1) 1/16" • #21 Mounting Bar 	1	1770
R	<ul style="list-style-type: none"> • F593C 3.00" Bolt • HDG (Galvanized) Impact Plate • HDG (Galvanized) Spacers – (1) 3/4"; (1) 1/2"; (1) 1/16" • HDG (Galvanized) Mounting Bar 	1	1770

Following the test, the breakaway torque required to loosen the bolt was recorded, and the DUT was removed from the test area. A visual examination of the DUT was conducted.

A pendulum hammer with a one (1) meter swing arm and a minimum 7.4-kilogram hammer were used and swung from a height of approximately one (1) meter. An accelerometer was attached to the impact hammer. A 1/2" thick impact-resistant PVC plate was attached to the impact plate for each orientation. A GoPro camera was used to capture high speed video of each test.

11.1.3. Description of Test Apparatus:

Eq ID	Equipment Description	Manufacturer	Model No.	Serial No.	Frequency Range	Cal Date	Due Date
CGP1	GOPRO CAMERA	GOPRO	HERO8 BLACK	C3331350162200	---	CNR	
ELF2	VIBRATION VIEW I/O BOX	VIBRATION RESEARCH	VIBRATION VIEW	0B3C8843	---	12	
XAE2	SHOCK ACCELEROMETER	PCB PIEZOTRONICS	350B03	20158	2HZ-10KHZ	4/1/2021	4/1/2022
XWN2	TORQUE WRENCH	PROTO	JH5-100FRB	01163500	100FT/LB	4/28/2021	4/28/2022
XZJ2	IK IMPACT TEST MACHINE	ELITE	IEC 60068-2-75	---	---	9/2/2021	9/2/2023

I/O: Initial Only N/A: Not Applicable CNR: Calibration Not Required

Note 1: For the purpose of this test, the equipment was calibrated prior to the test or monitored by a calibrated instrument.

11.1.4. Test Results:

The DUTs were subjected to and completed the bolt shear impact test per the Customer Test Plan and the Environmental Procedure: FAA EB83A Bolt Shear Impact rev1.0. The peak force applied to each DUT and post-test observations can be seen below. The DUTs were returned to the customer for further evaluation.

The observations and comparisons of each DUT orientation led to the following conclusions about the behavior of the in-pavement light fixture bolted connection described in FAA EB83A:

1. Both Grade 5 and F593C bolts provide sufficient clamping force and shear strength to withstand

- the applied shear impact loads without breakage or excessive deformation for all faying surface coatings evaluated.
2. Both Grade 5 and F593C bolts bend under shear impact load and are likely to fail due to bending fatigue after multiple impacts.
 3. Bolt bending indicates that the bolted connection acts as a bearing joint rather than a friction joint under shear impact load.
 4. Higher friction coefficients on the faying surfaces reduce shear load and bolt bending under the same clamping force.
 5. The #21 friction coating proved to be more durable than the B50 friction coating.
 6. Bolt clamping force is not critical to the integrity of the bolted connection as a bearing joint. Grade 5 bolts at 4900 lb and F593C bolts at 3800 lb clamping force demonstrated similar bending and deformation under similar shear impact loads.

Orientation	Pretest Torque (ftlb)	Breakaway Torque (ftlb)	Peak Force (lbf)	Duration (ms)	Corrected Duration (ms)	Observations
A	61.8	-	4877.675	0.55	N/A	Significant bending.
A1	63.1	19.9	4314.175	0.55	N/A	Significant bending in two sections. For strike 3, there was some ringing in the fixture. A corrected duration for the initial hit was determined.
			3928.255	0.55	N/A	
			3473.017	6.55	0.50	
B	45.3	12.3	3971.698	7.30	0.65	Significant bending. There was some ringing in the fixture. A corrected duration for the initial hit was determined.
C	42.6	19.1	4012.632	7.45	0.60	Slight bending. There was some ringing in the fixture. A corrected duration for the initial hit was determined.
D	43.4	12.0	4541.454	6.65	0.60	Slight bending. There was some ringing in the fixture. A corrected duration for the initial hit was determined.
E	43.0	18.9	3964.204	0.55	N/A	Slight bending
E1	42.5	15.1	4419.703	0.55	N/A	Significant bending in two sections. For strike 2 and 3, there was some ringing in the fixture. A corrected duration for the initial hit was determined.
			4102.92	6.50	0.65	
			3839.141	6.75	0.65	
G	42.5	15.8	4512.568	0.60	N/A	Significant bending.
H	42.9	13.3	4924.993	0.65	N/A	Slight bending.
I	42.6	8.6	4491.204	5.05	0.60	Slight bending. There was some ringing in the fixture. A corrected duration for the initial hit was determined.

I1	43.2	15.5	4813.994	4.75	0.55	Slight bending. For strike 1, there was some ringing in the fixture. A corrected duration for the initial hit was determined.
			4274.13	0.60	N/A	
			4207.865	0.50	N/A	
M	42.5	5.9	4311.439	5.85	0.65	Slight bending. There was some ringing in the fixture. A corrected duration for the initial hit was determined.
N	62.9	53.9	3141.896	0.80	N/A	Little to no bending.
O	42.7	23.3	2923.946	6.50	0.75	Little to no bending. There was some ringing in the fixture. A corrected duration for the initial hit was determined.
P	42.9	15.3	2907.17	6.15	0.65	Little to no bending. There was some ringing in the fixture. A corrected duration for the initial hit was determined.
R	42.2	22.3	2817.721	0.60	N/A	Little to no bending.



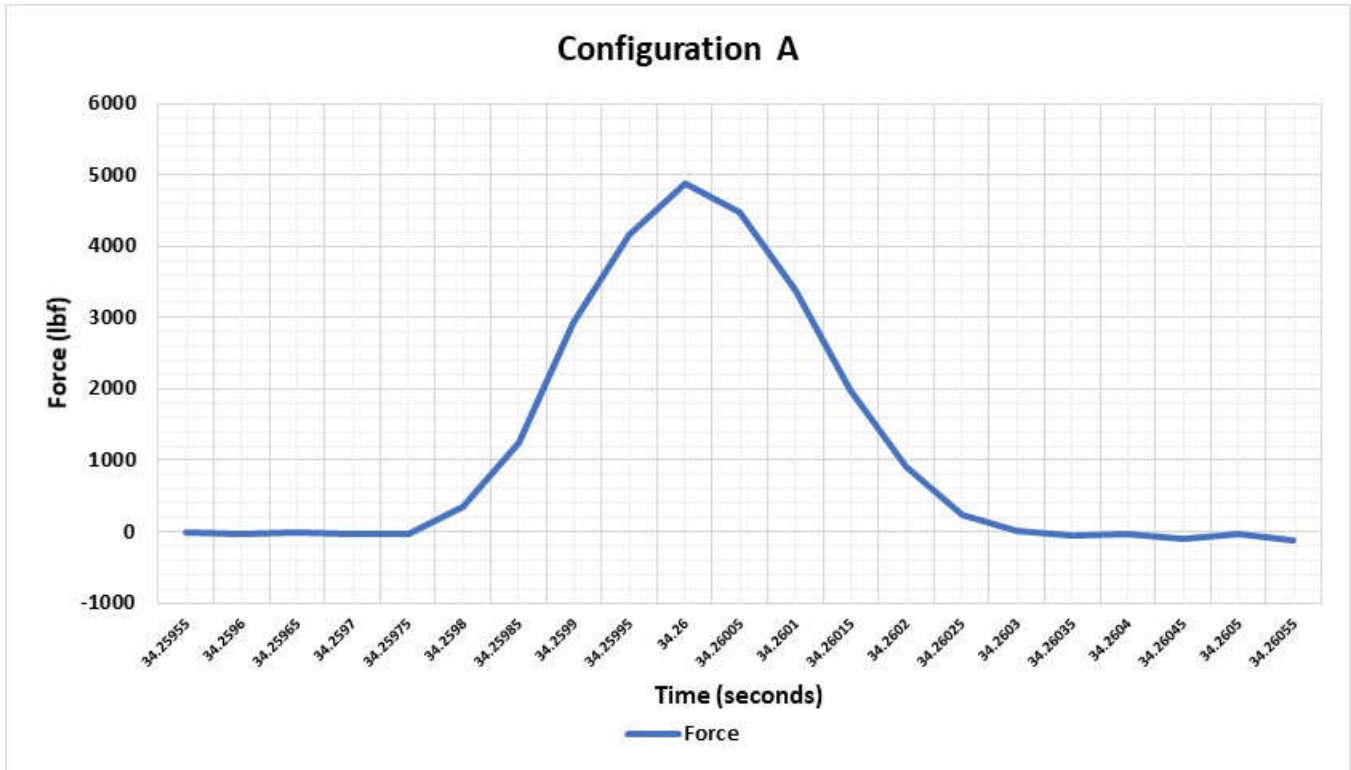
Test Setup Photograph



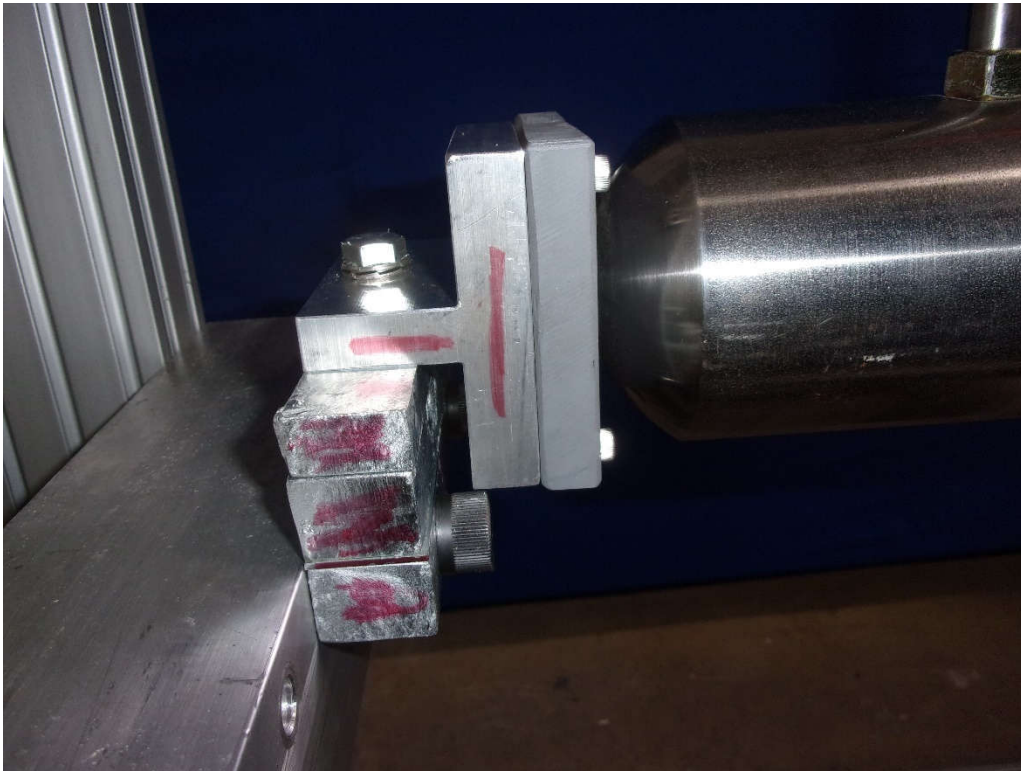
Test Setup Photograph (Orientation A)



Post-test Photograph (Orientation A)



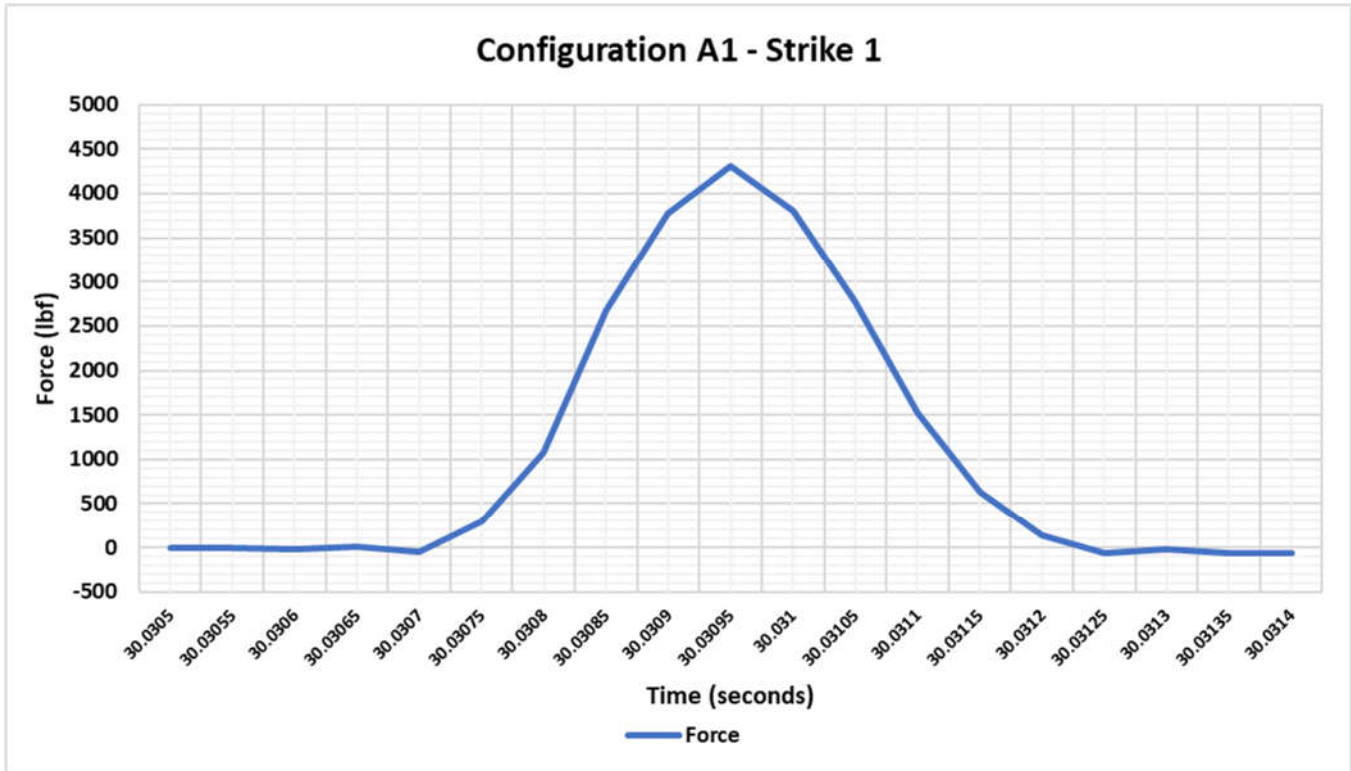
Force Graph



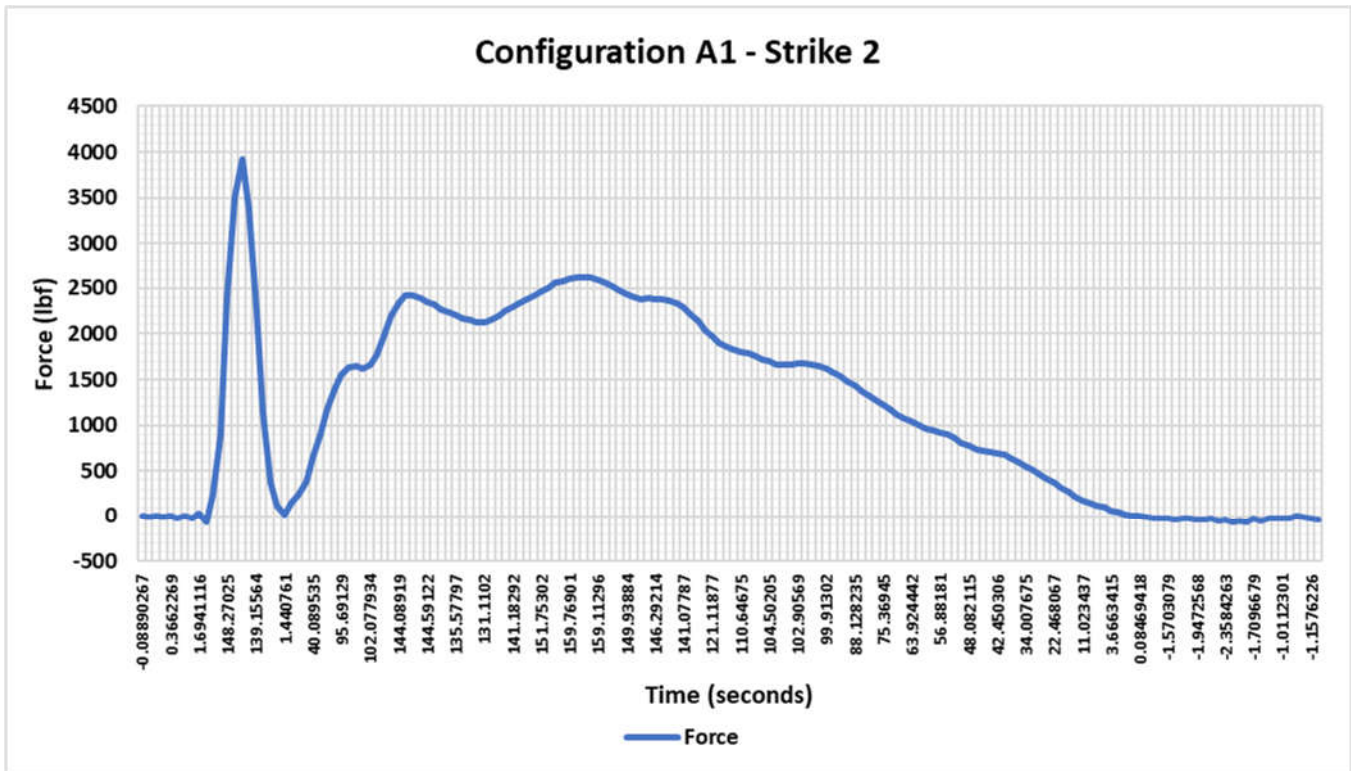
Test Setup Photograph (Orientation A1)



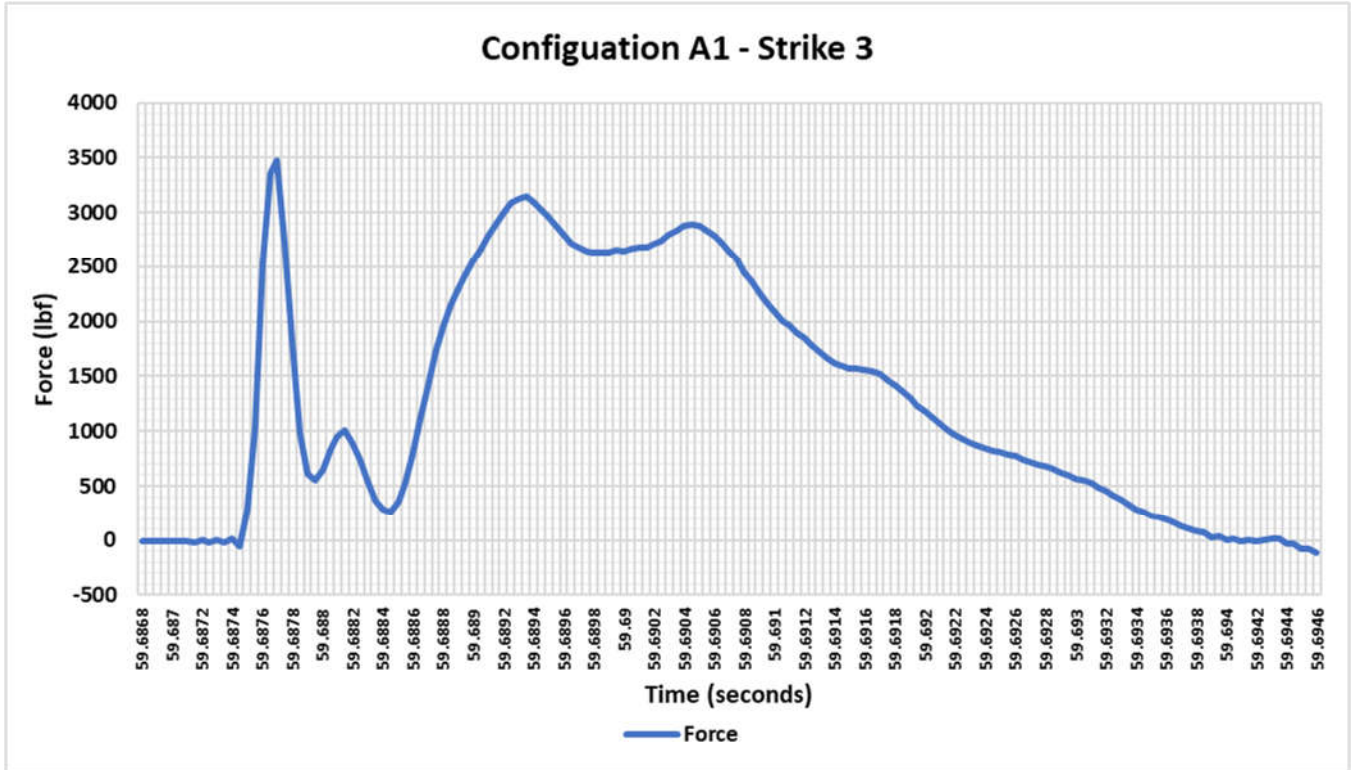
Post-test Photograph (Orientation A1)



Force Graph (Strike 1)

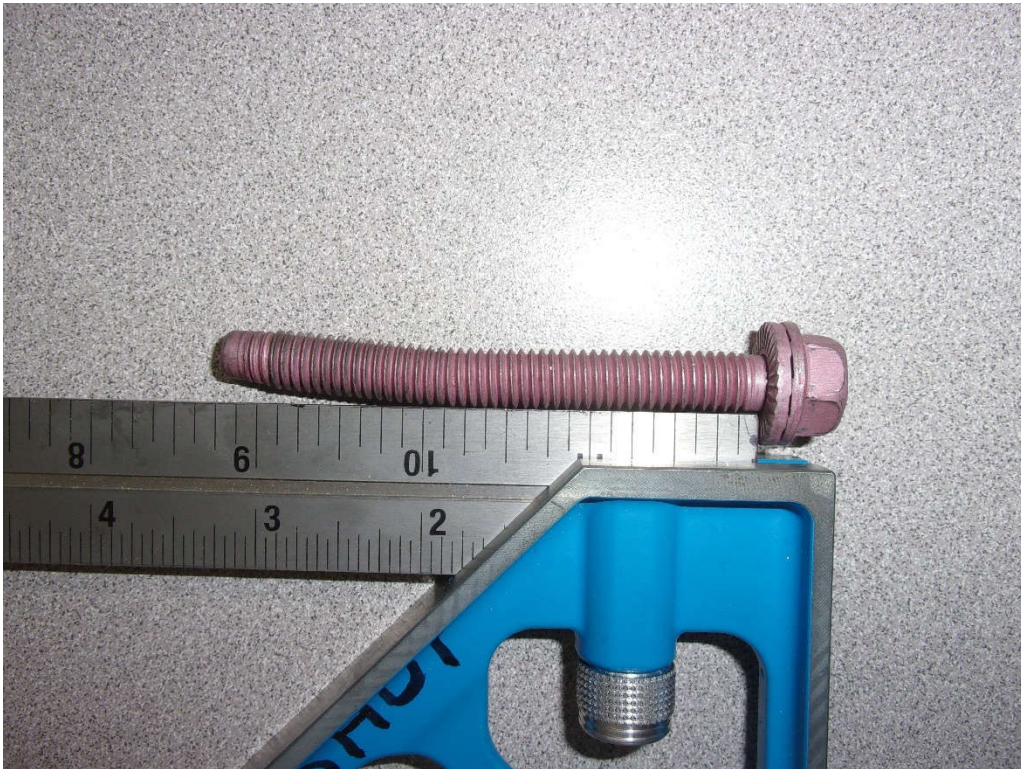


Force Graph (Strike 2)

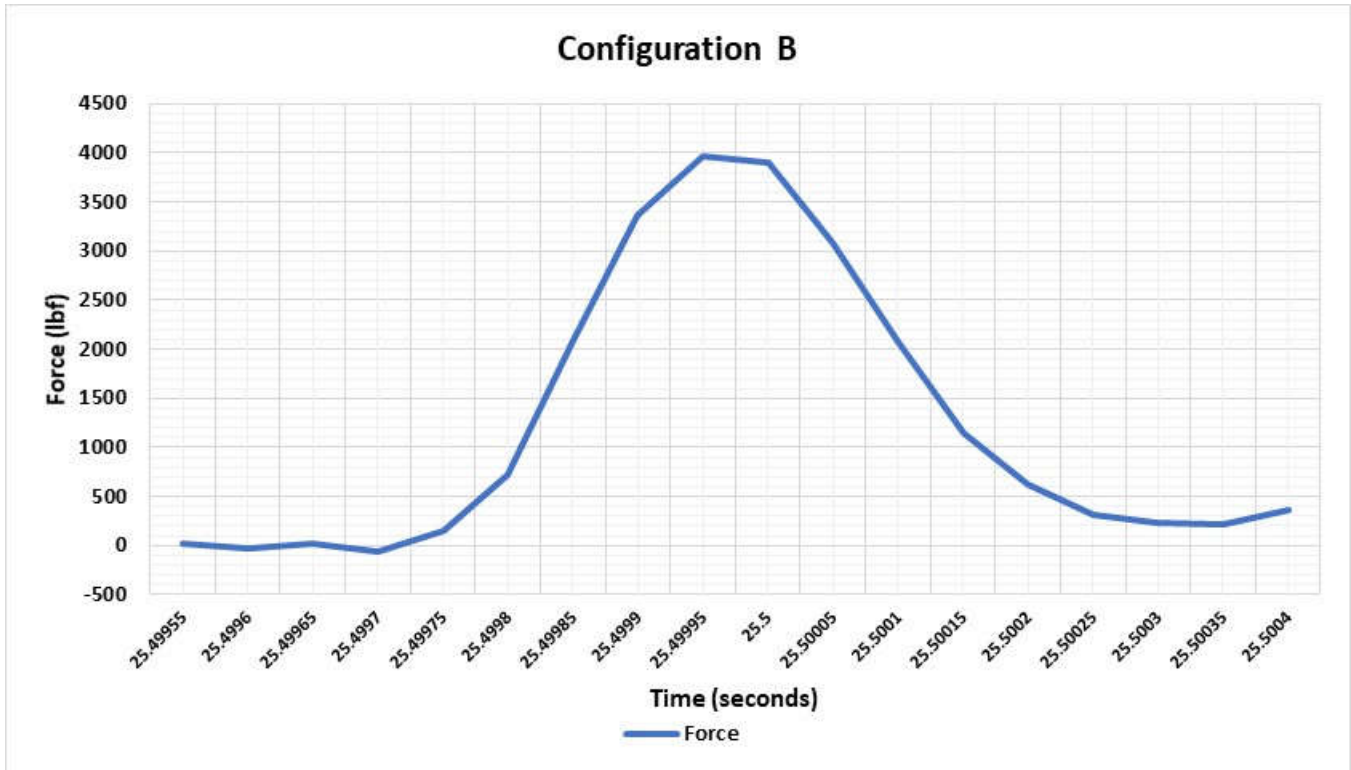




Test Setup Photograph (Orientation B)



Post-test Photograph (Orientation B)



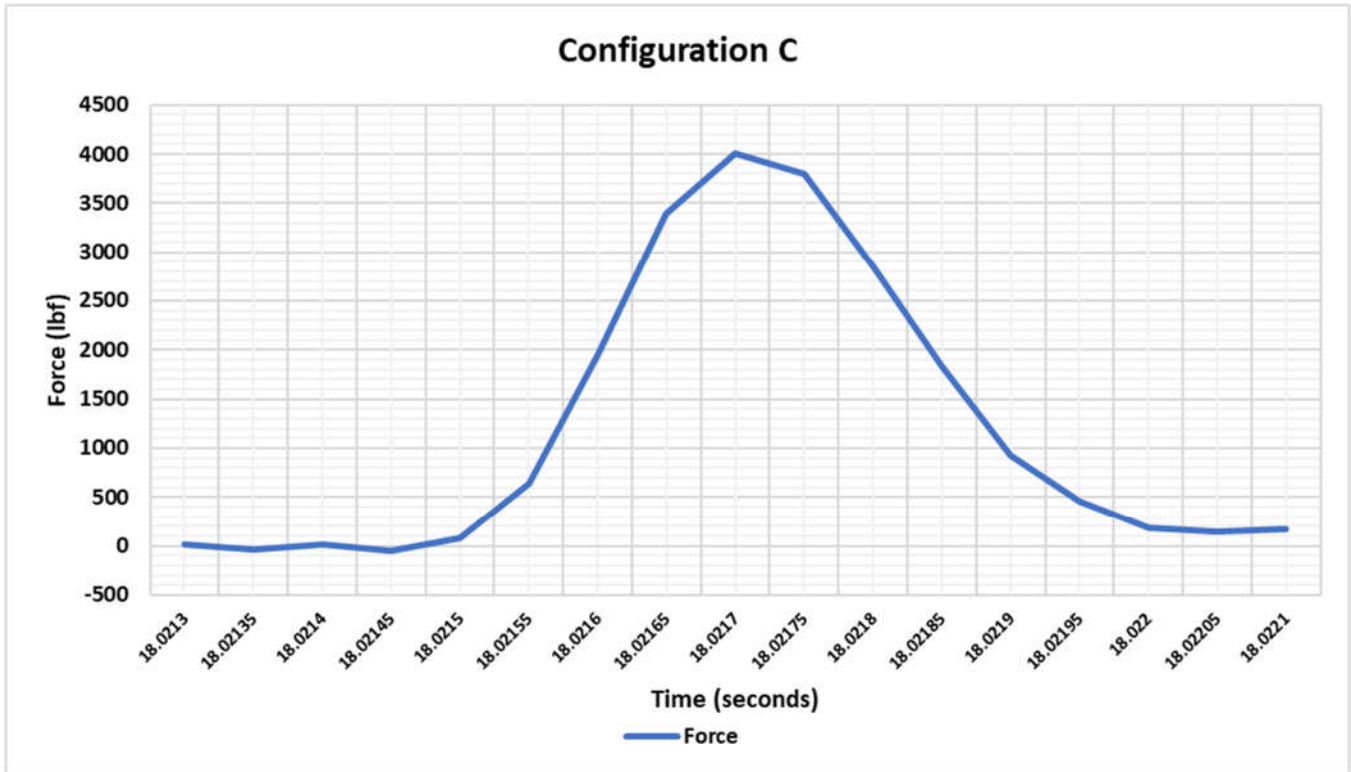
Force Graph



Test Setup Photograph (Orientation C)



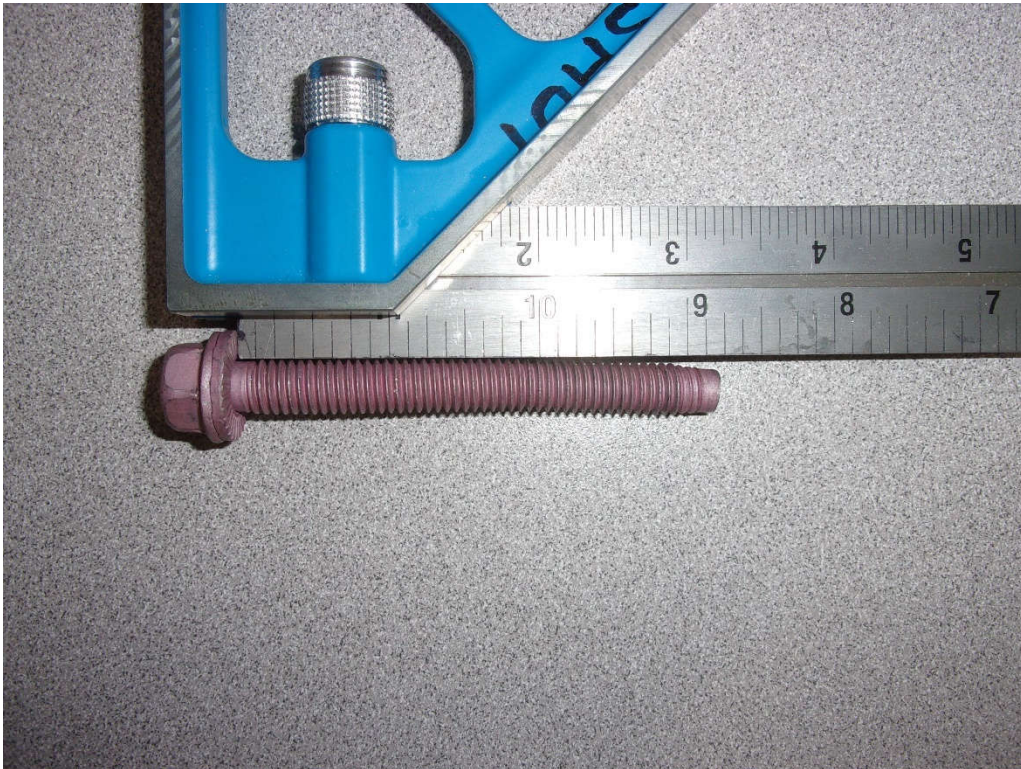
Post-test Photograph (Orientation C)



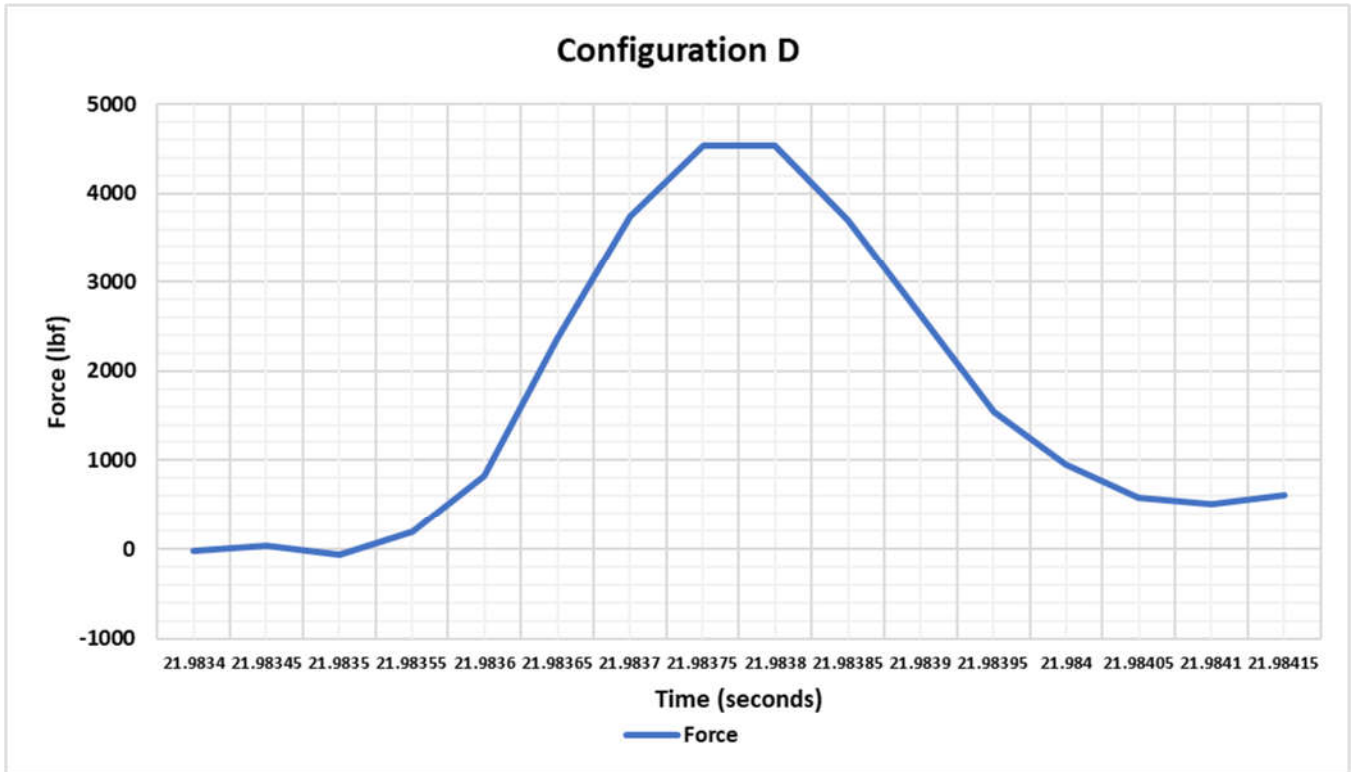
Force Graph



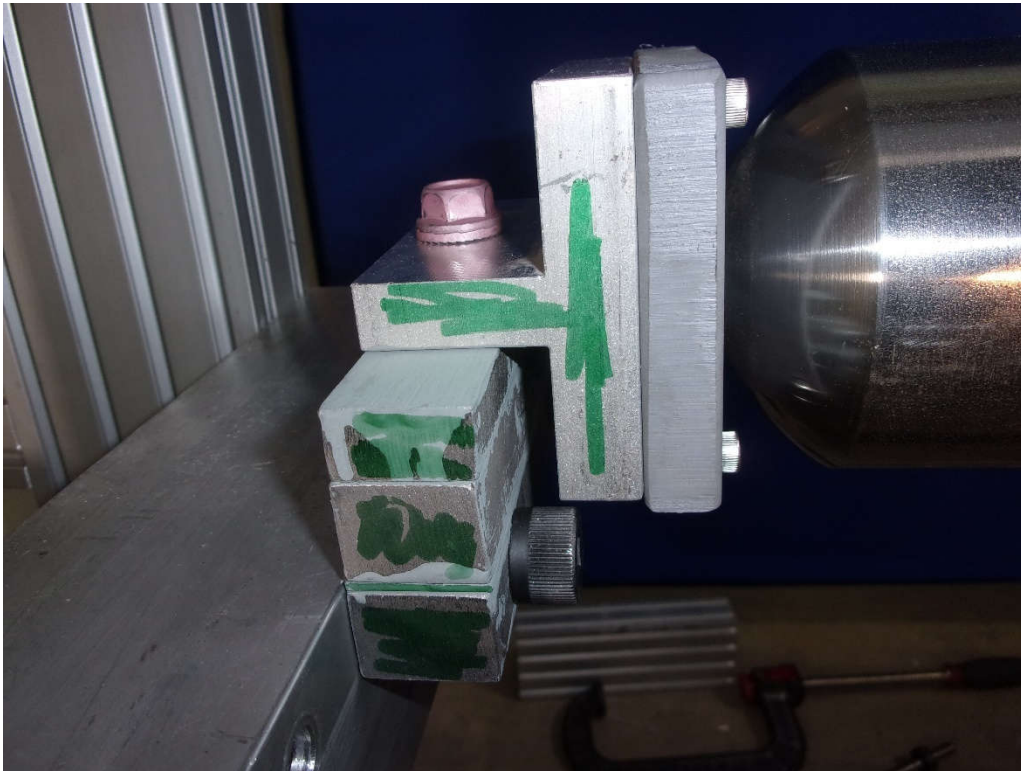
Test Setup Photograph (Orientation D)



Post-test Photograph (Orientation D)



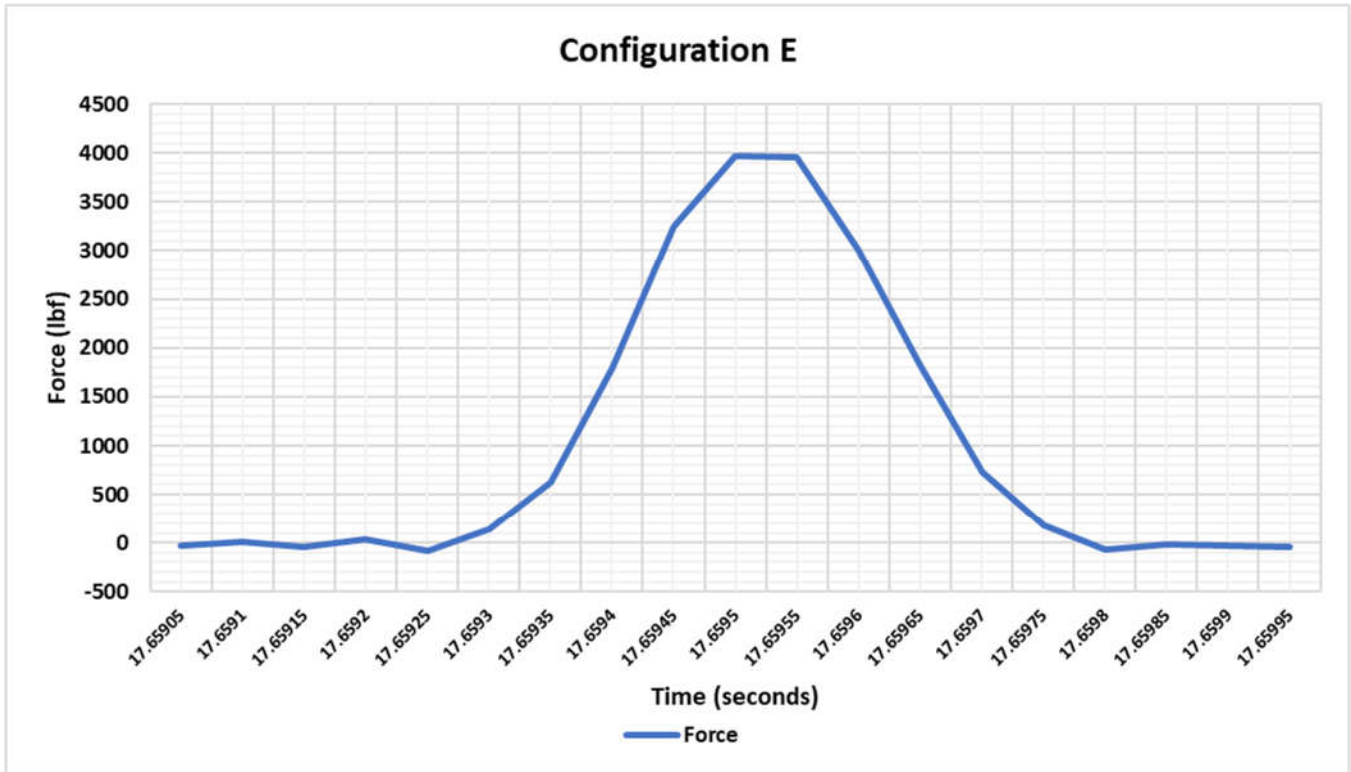
Force Graph



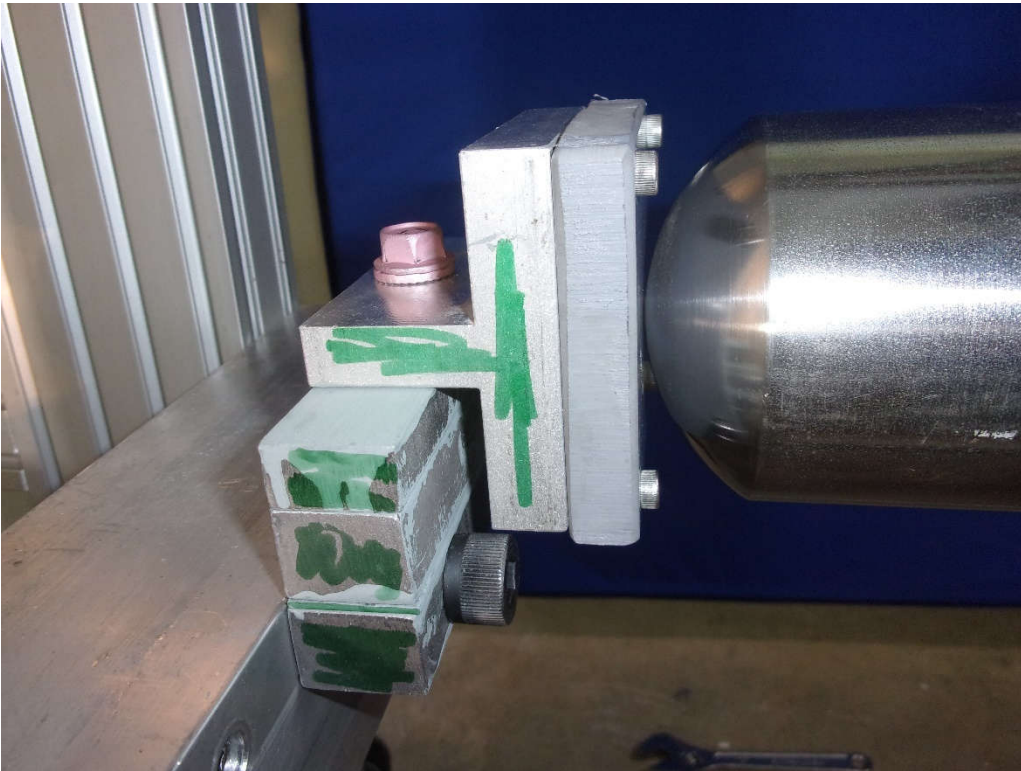
Test Setup Photograph (Orientation E)



Post-test Photograph (Orientation E)



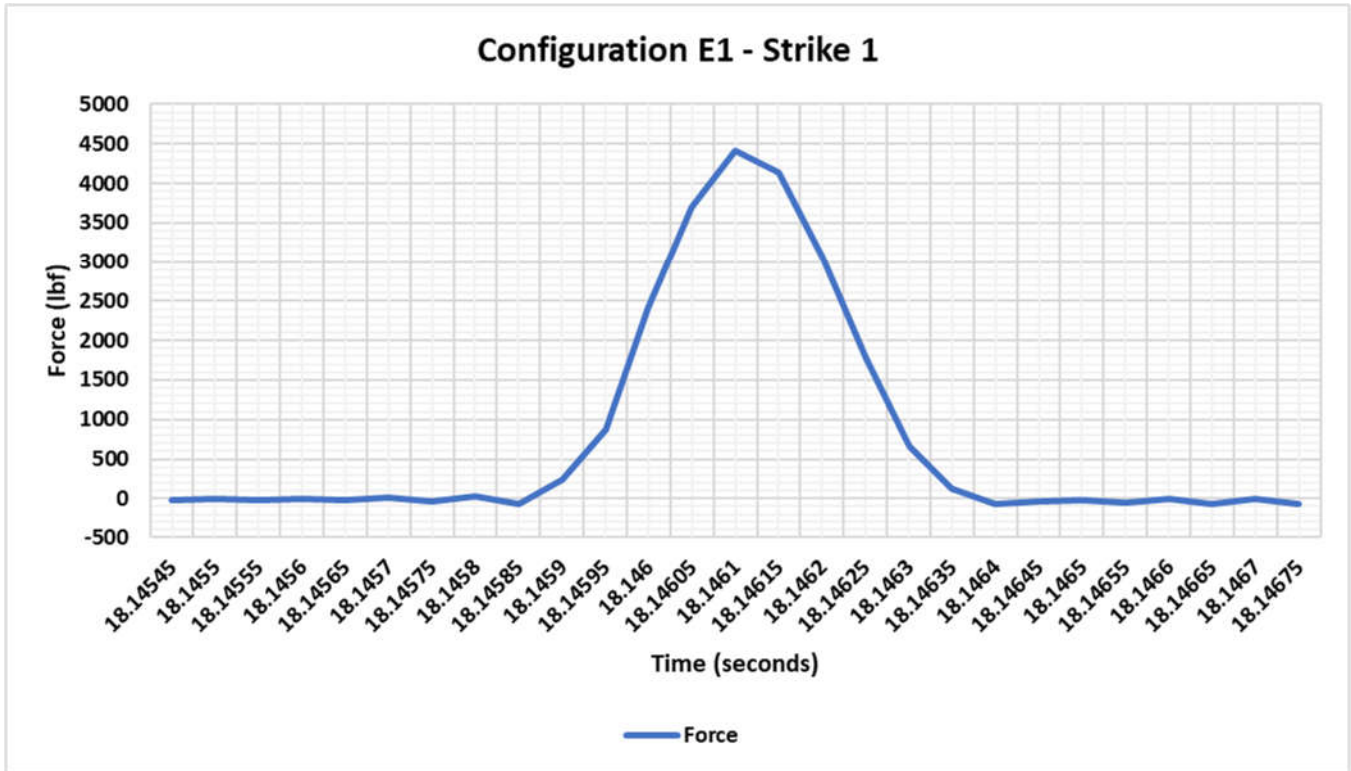
Force Graph



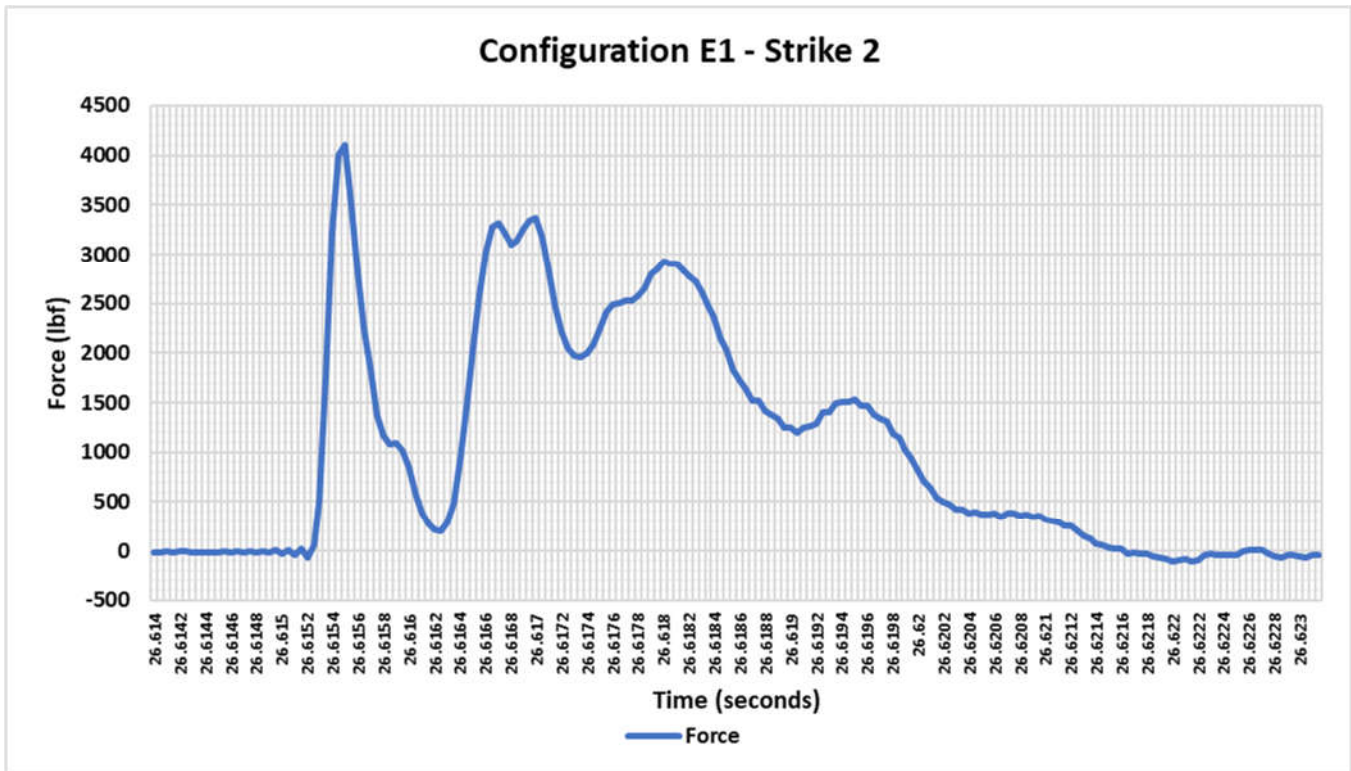
Test Setup Photograph (Orientation E1)



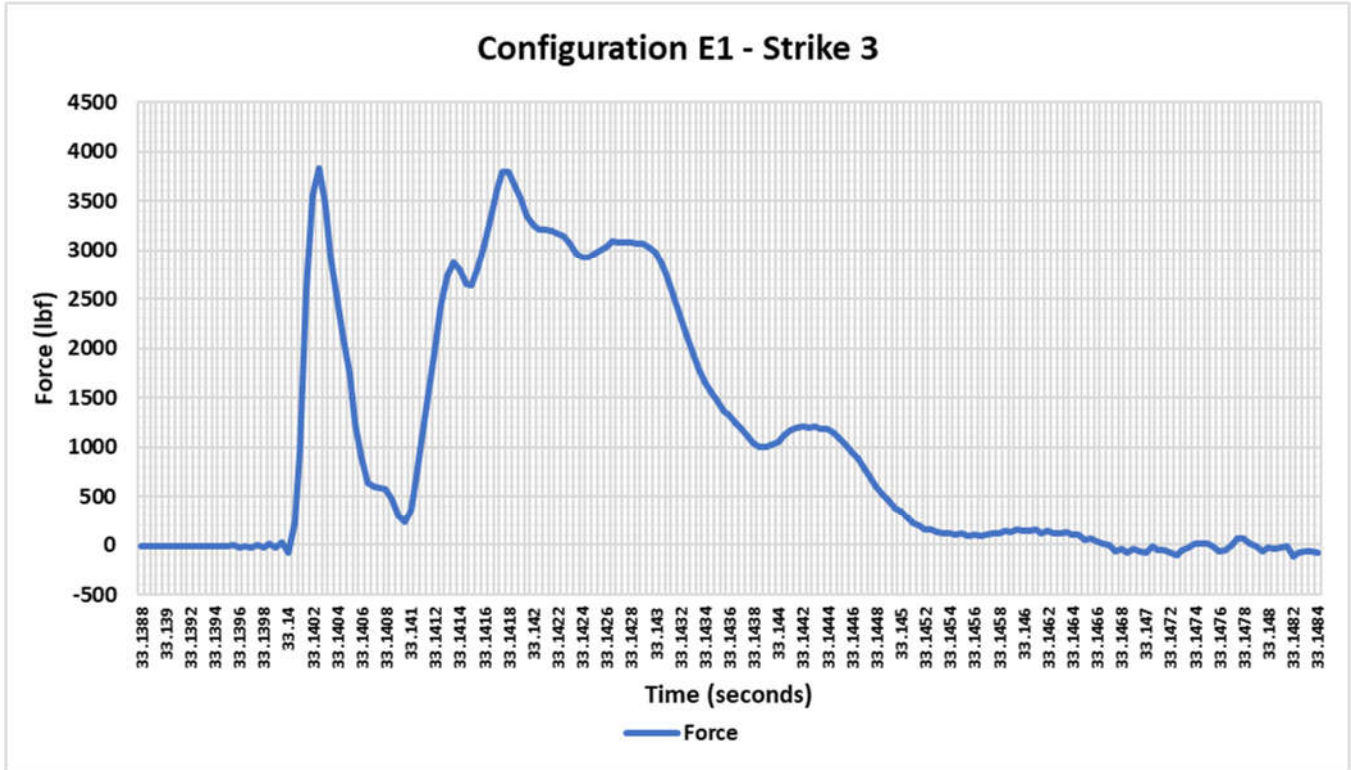
Post-test Photograph (Orientation E1)



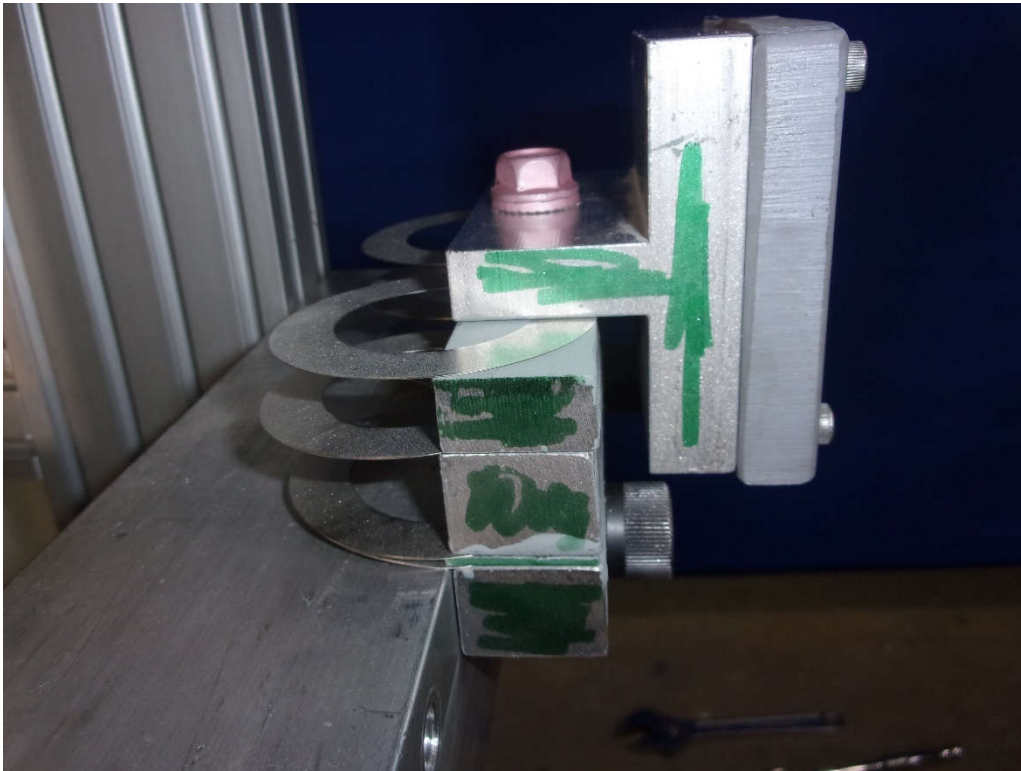
Force Graph (Strike 1)



Force Graph (Strike 2)



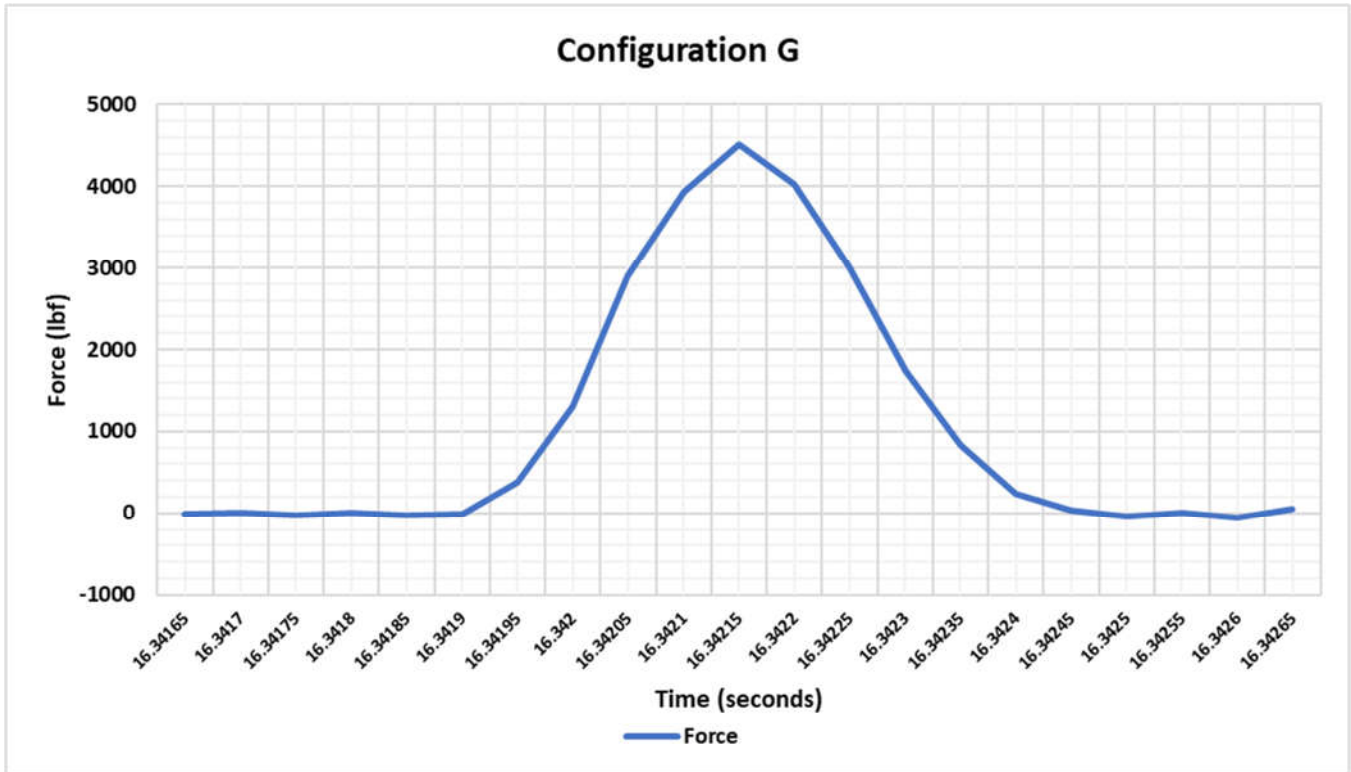
Force Graph (Strike 3)



Test Setup Photograph (Orientation G)



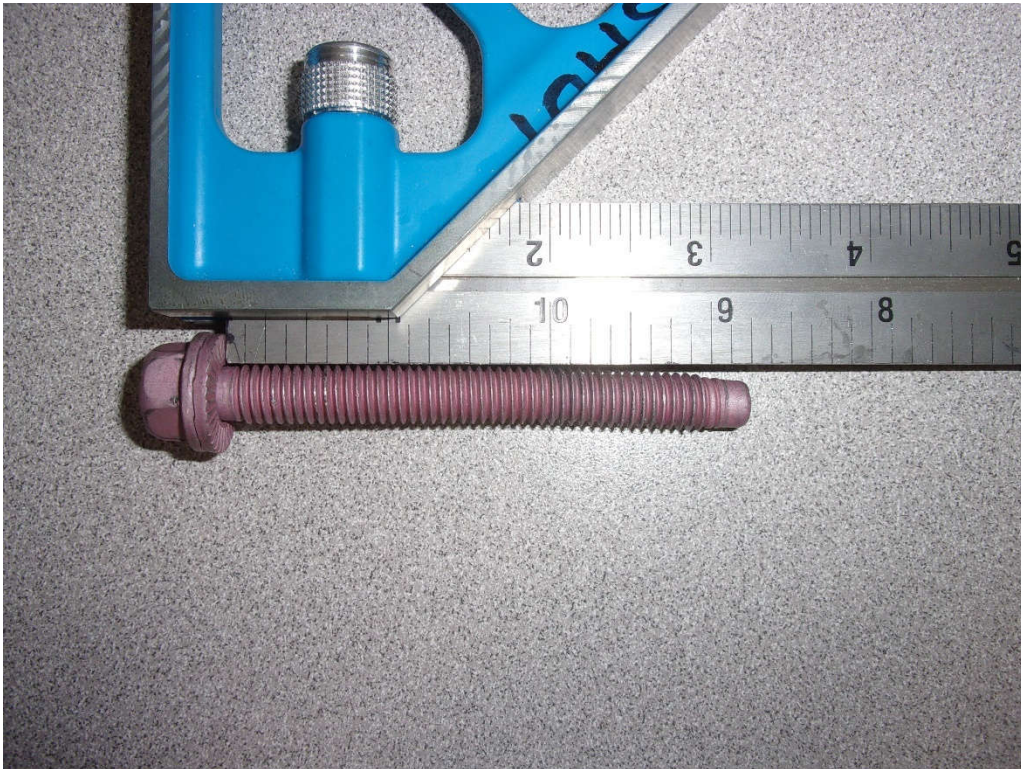
Post-test Photograph (Orientation G)



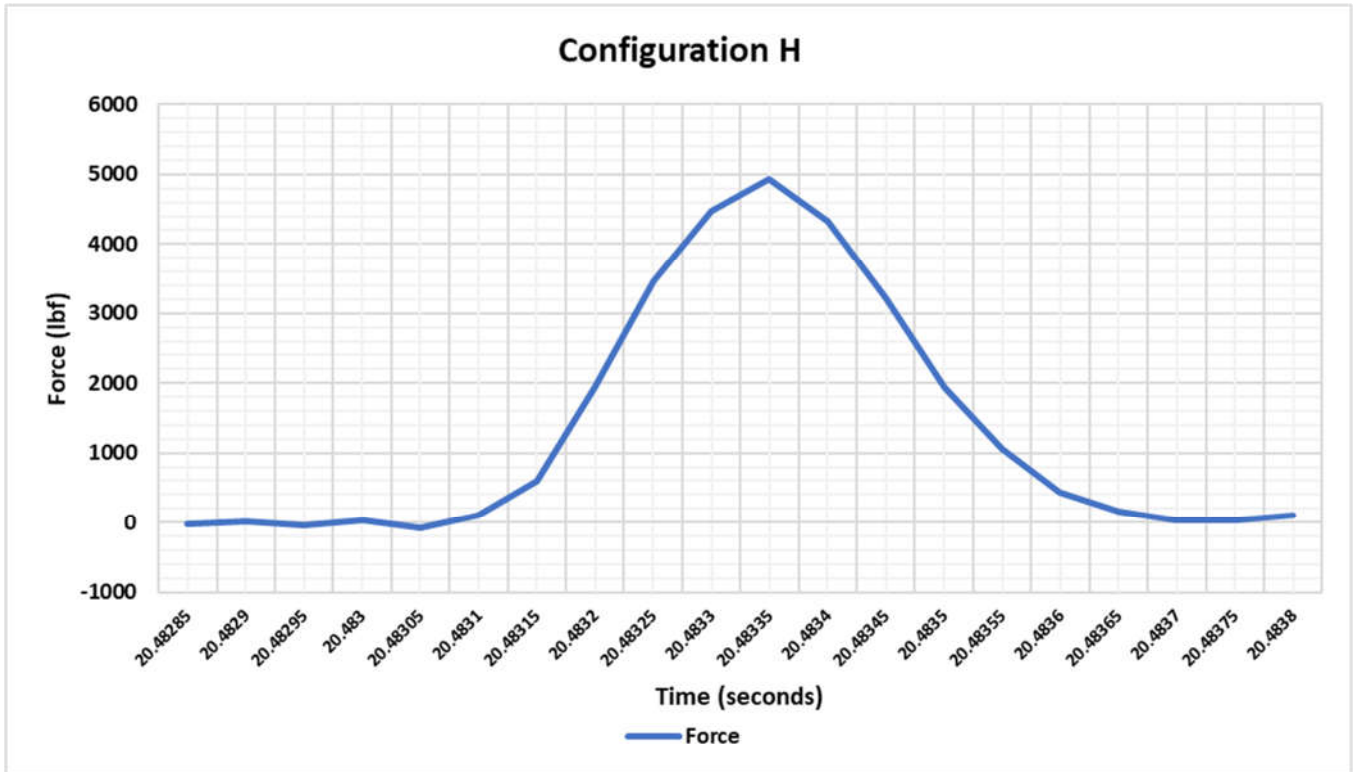
Force Graph



Test Setup Photograph (Orientation H)



Post-test Photograph (Orientation H)



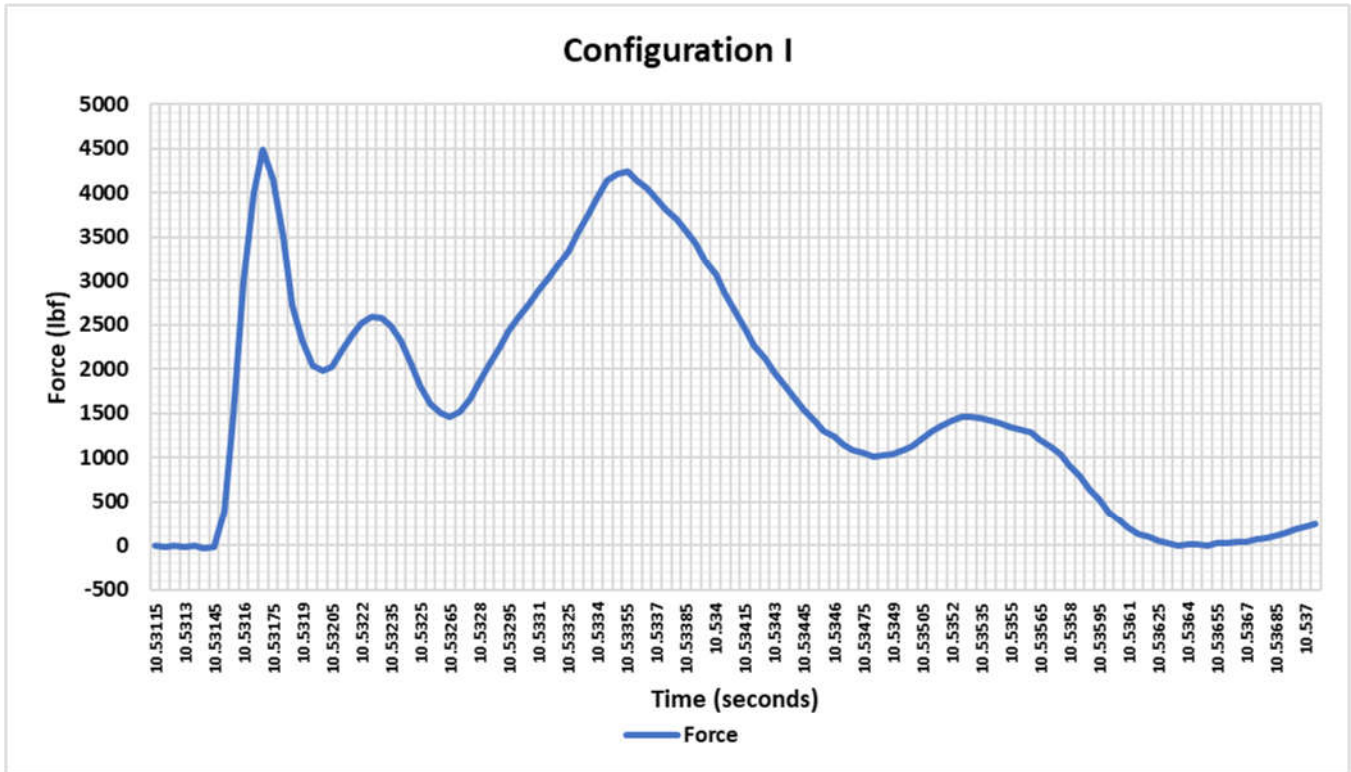
Force Graph



Test Setup Photograph (Configuration I)



Post-test Photograph (Orientation I)



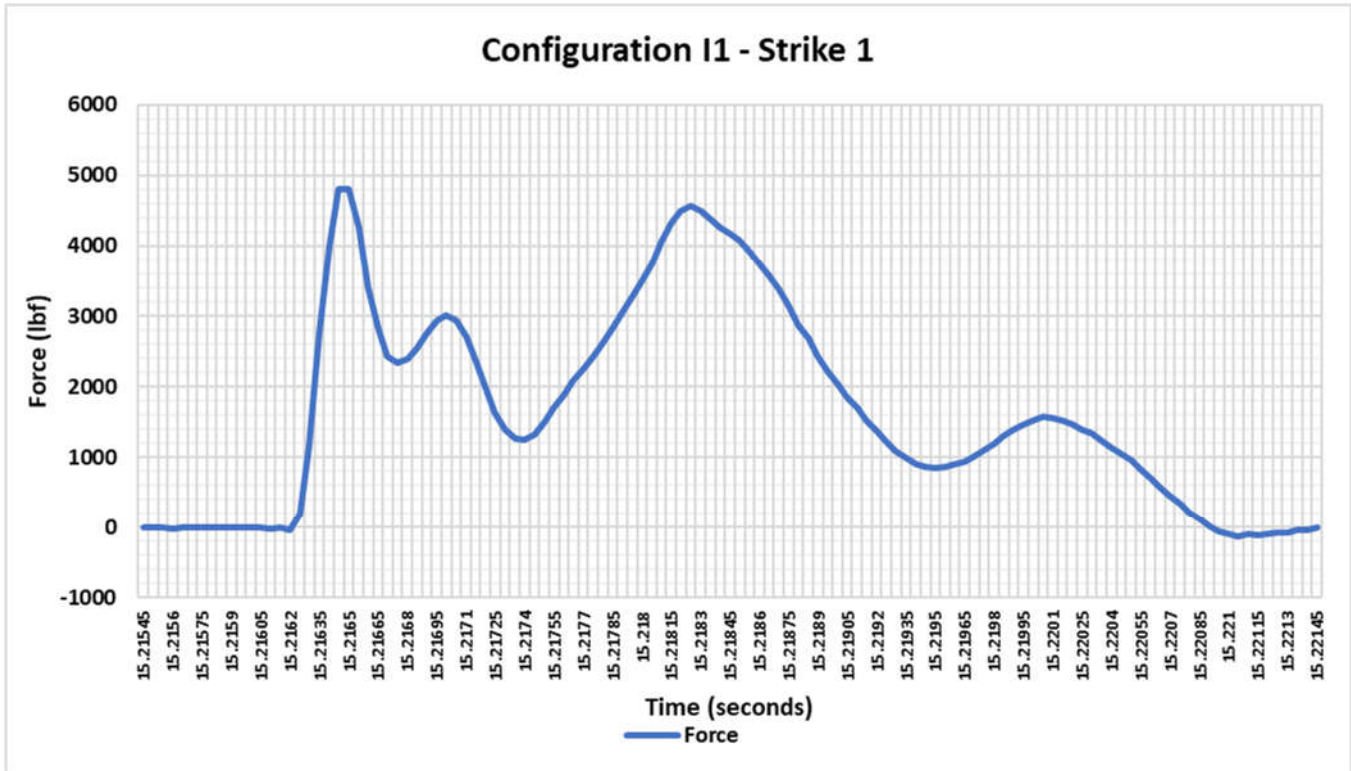
Force Graph



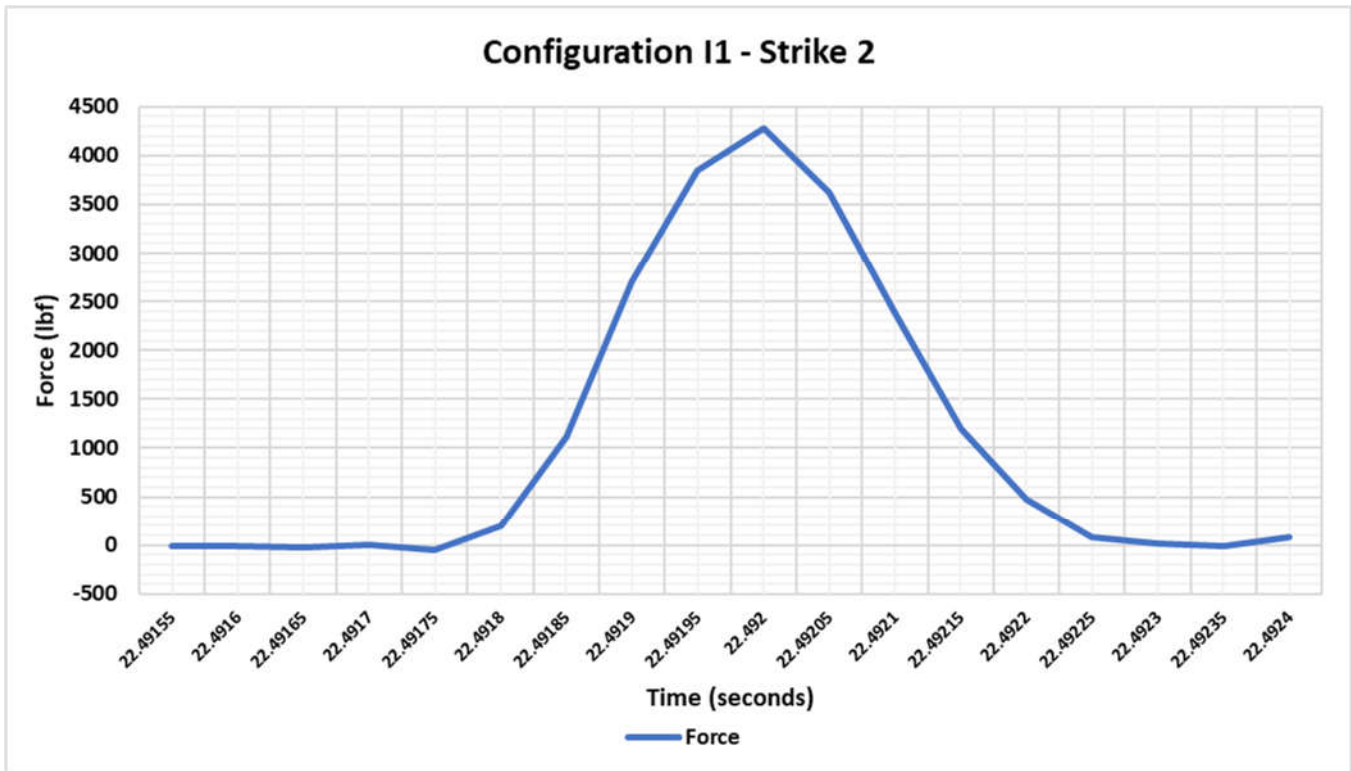
Test Setup Photograph (Orientation I1)



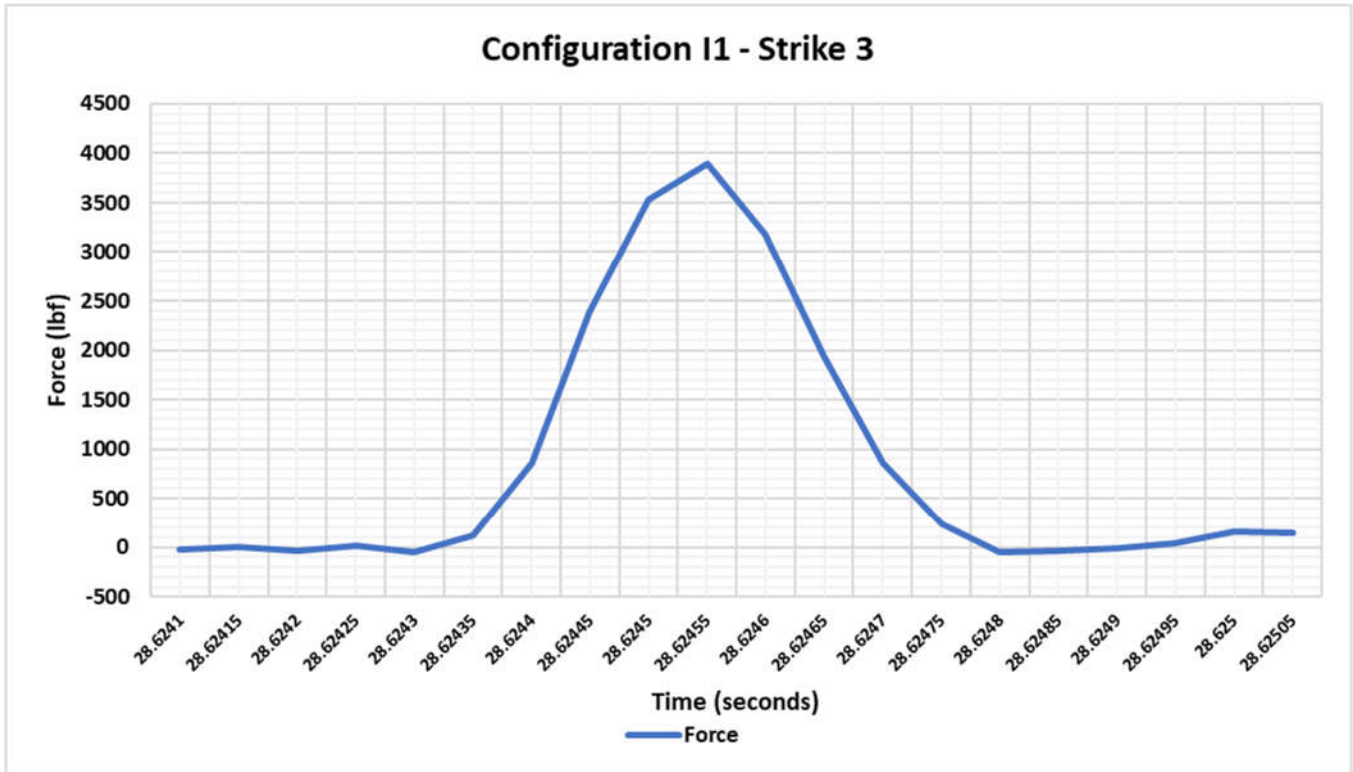
Post-test Photograph (Orientation I1)



Force Graph (Strike 1)



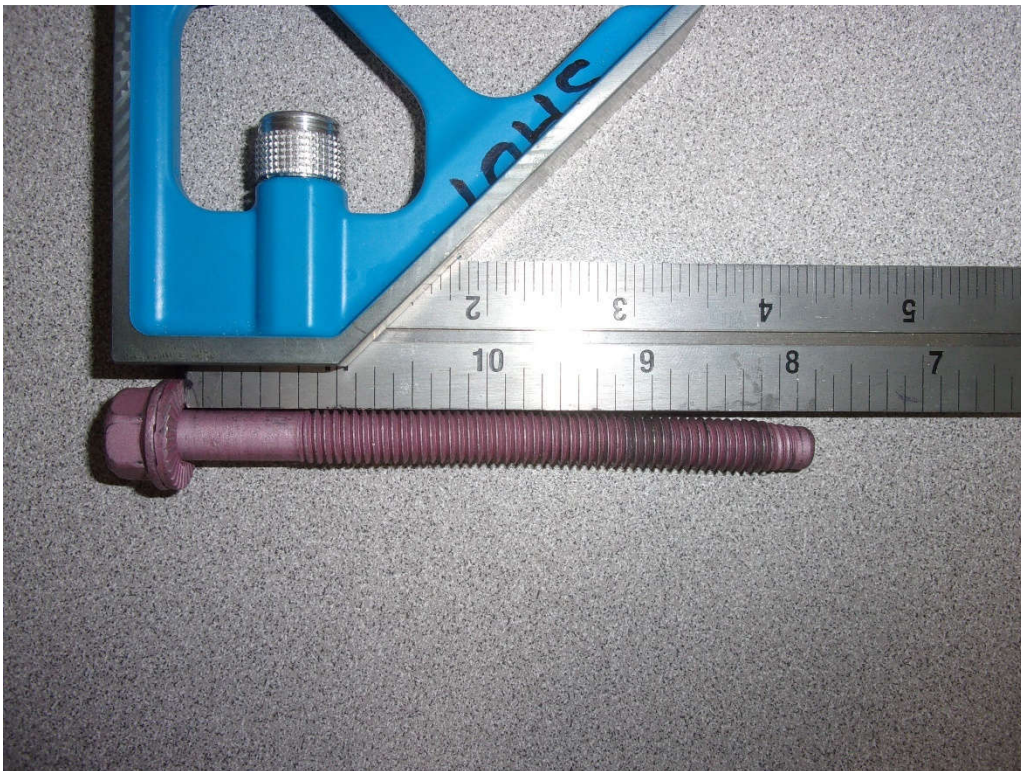
Force Graph (Strike 2)



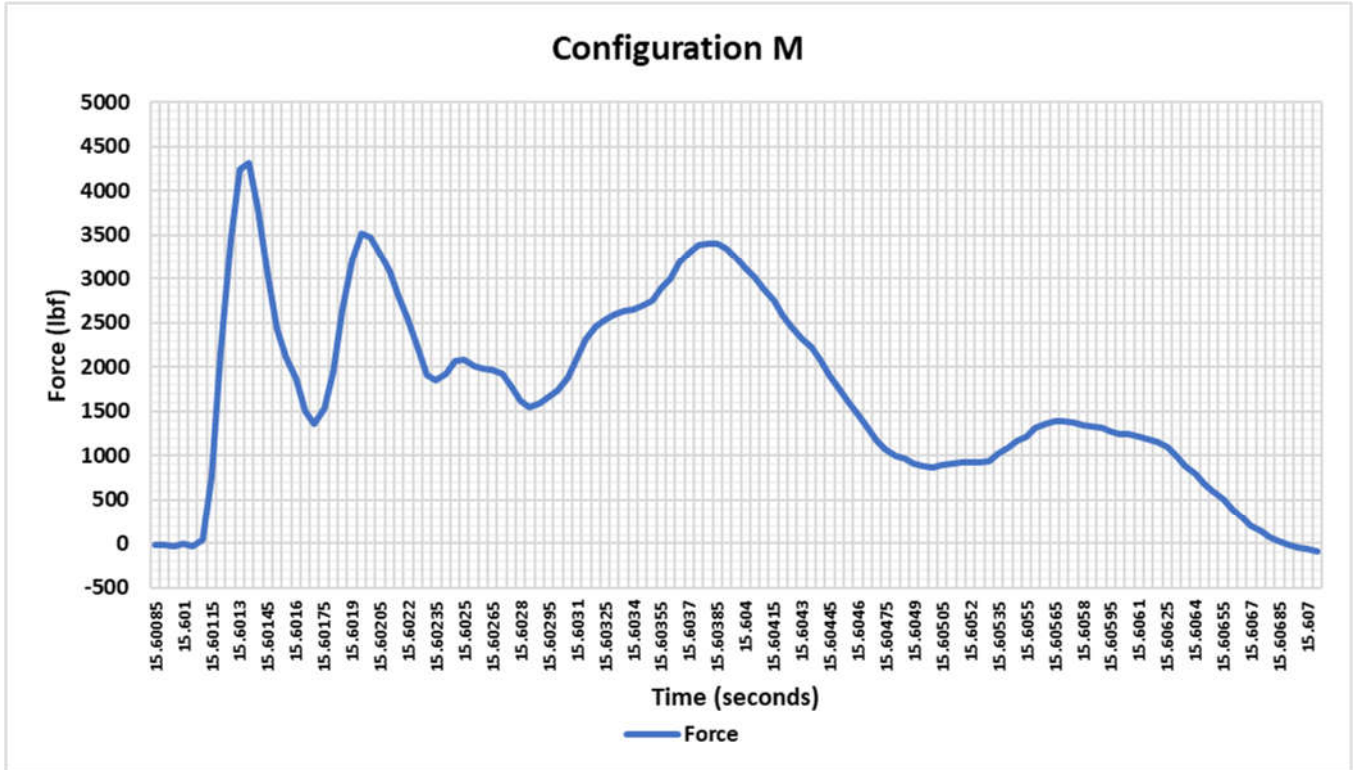
Force Graph (Strike 3)



Test Setup Photograph (Orientation M)



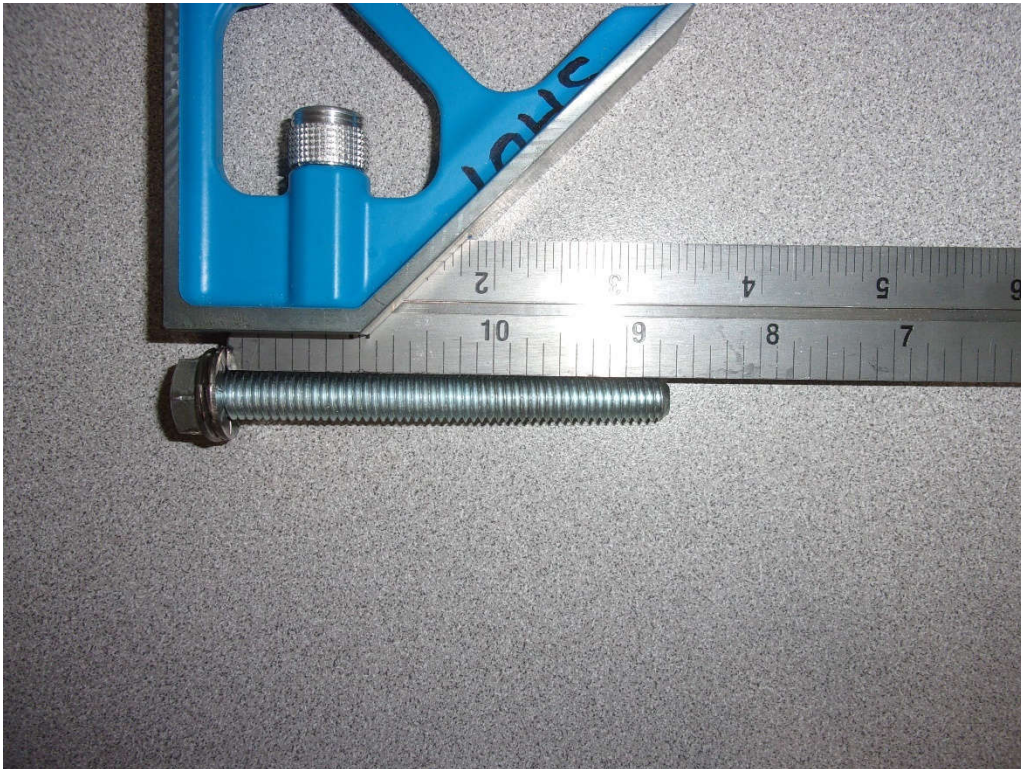
Post-test Photograph (Orientation M)



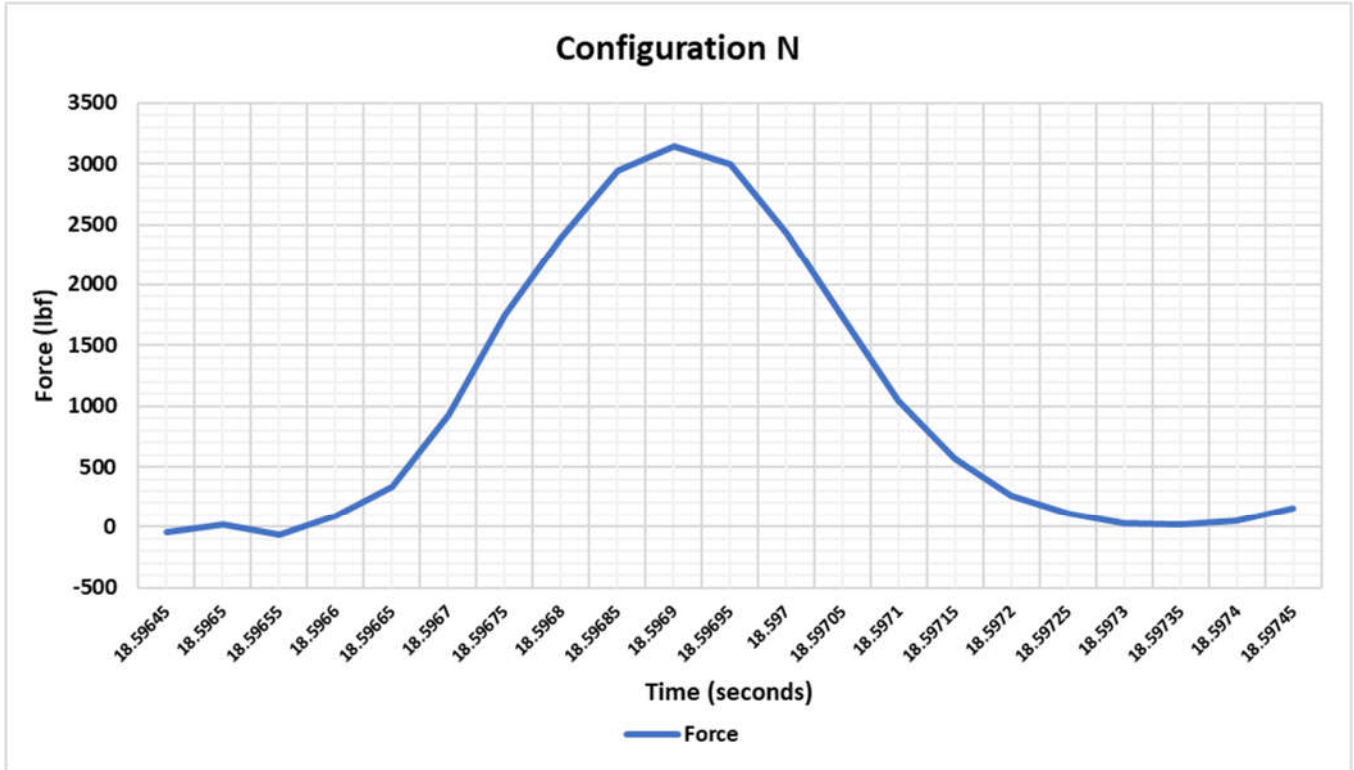
Force Graph



Test Setup Photograph (Orientation N)



Post-test Photograph (Orientation N)



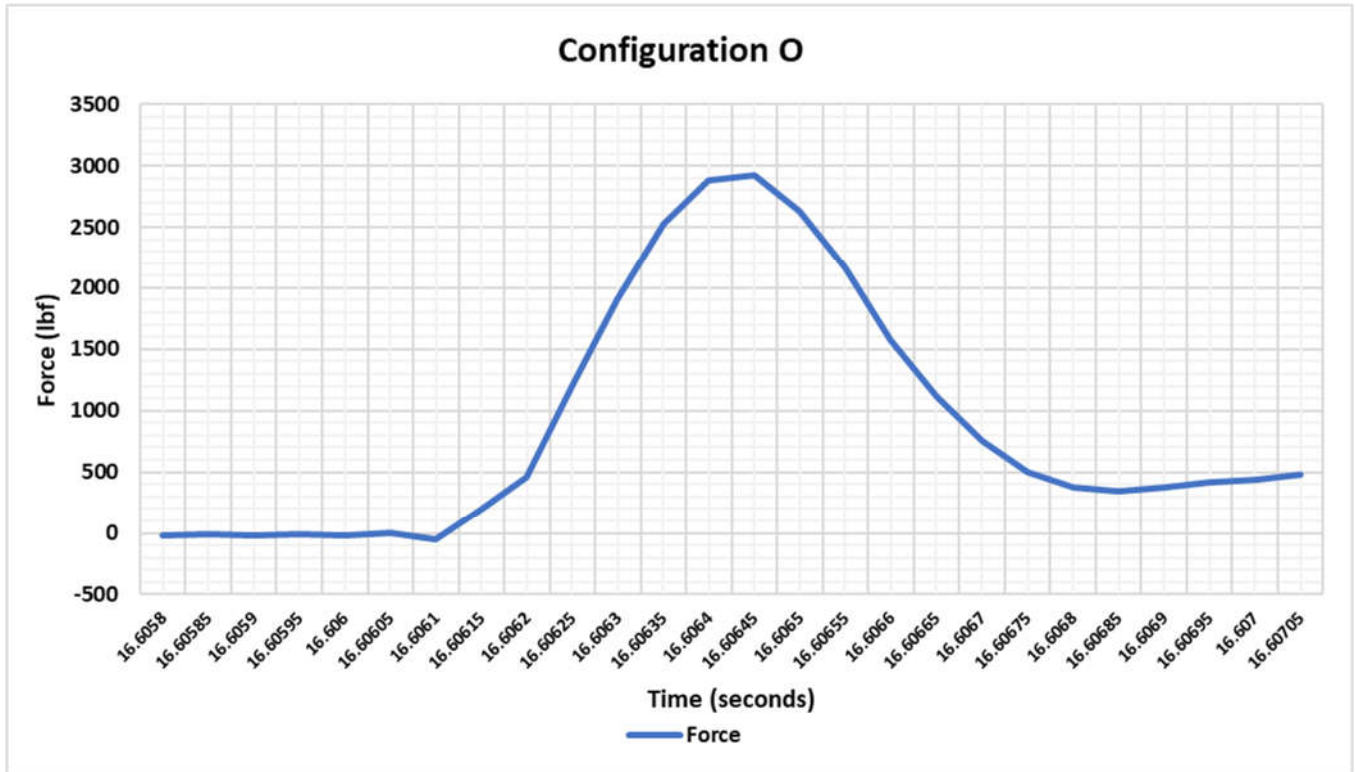
Force Graph



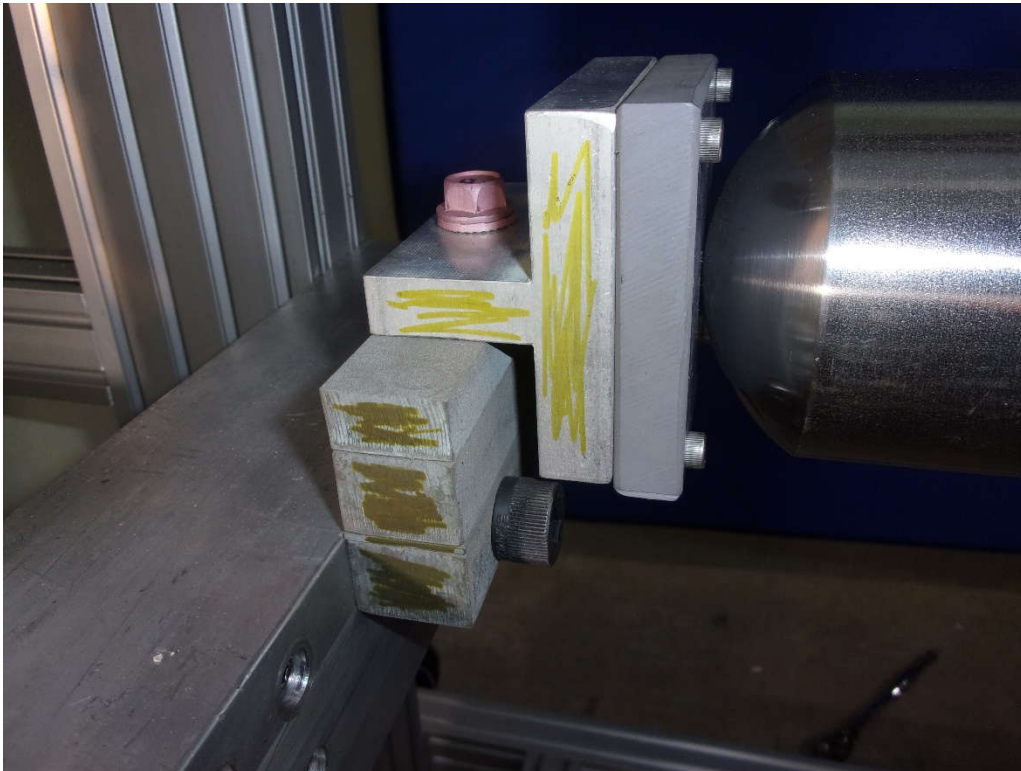
Test Setup Photograph (Orientation O)



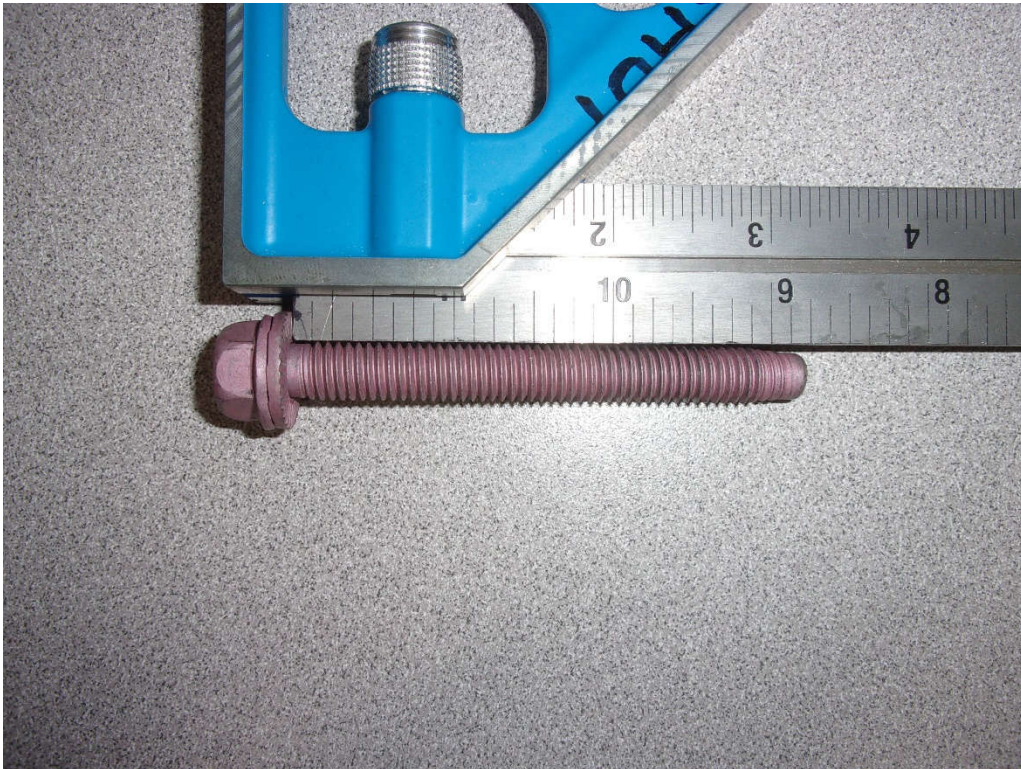
Post-test Photograph (Orientation O)



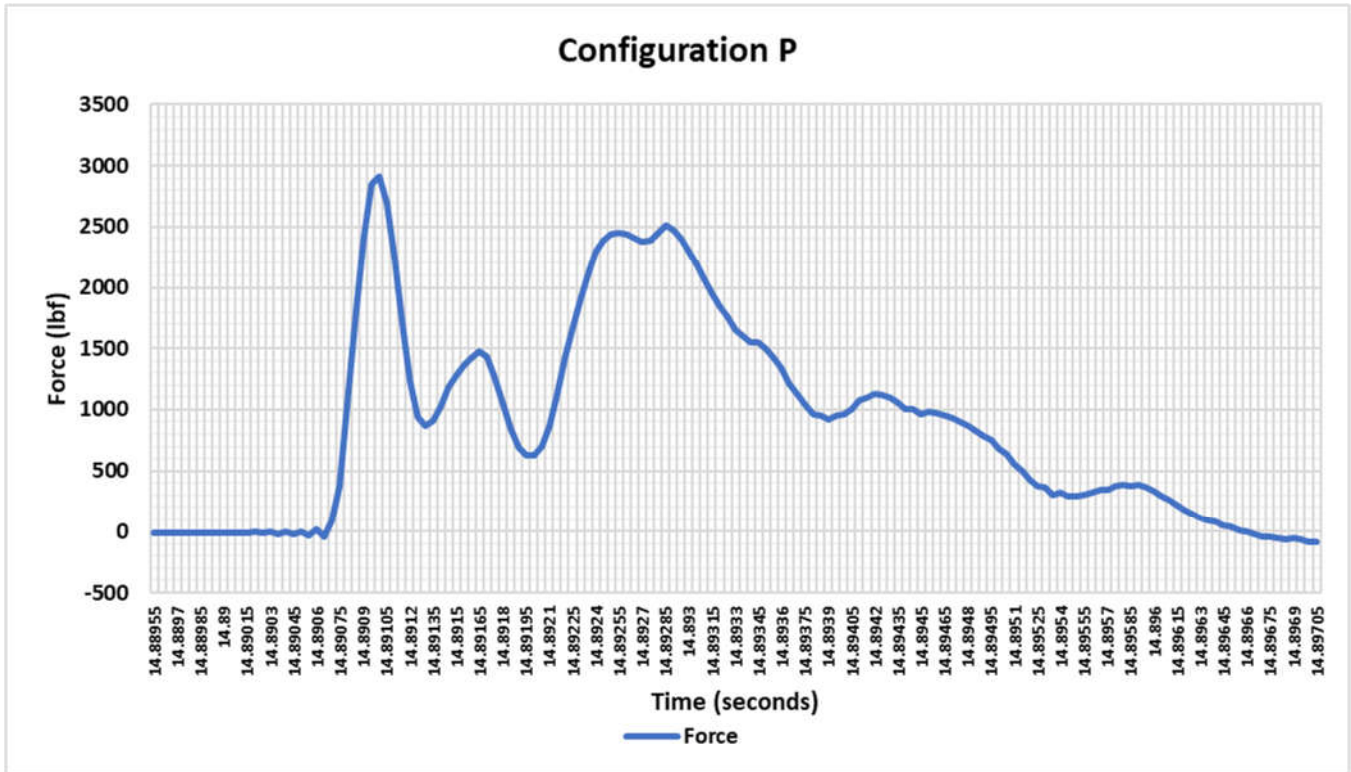
Force Graph



Test Setup Photograph (Orientation P)



Post-test Photograph (Orientation P)



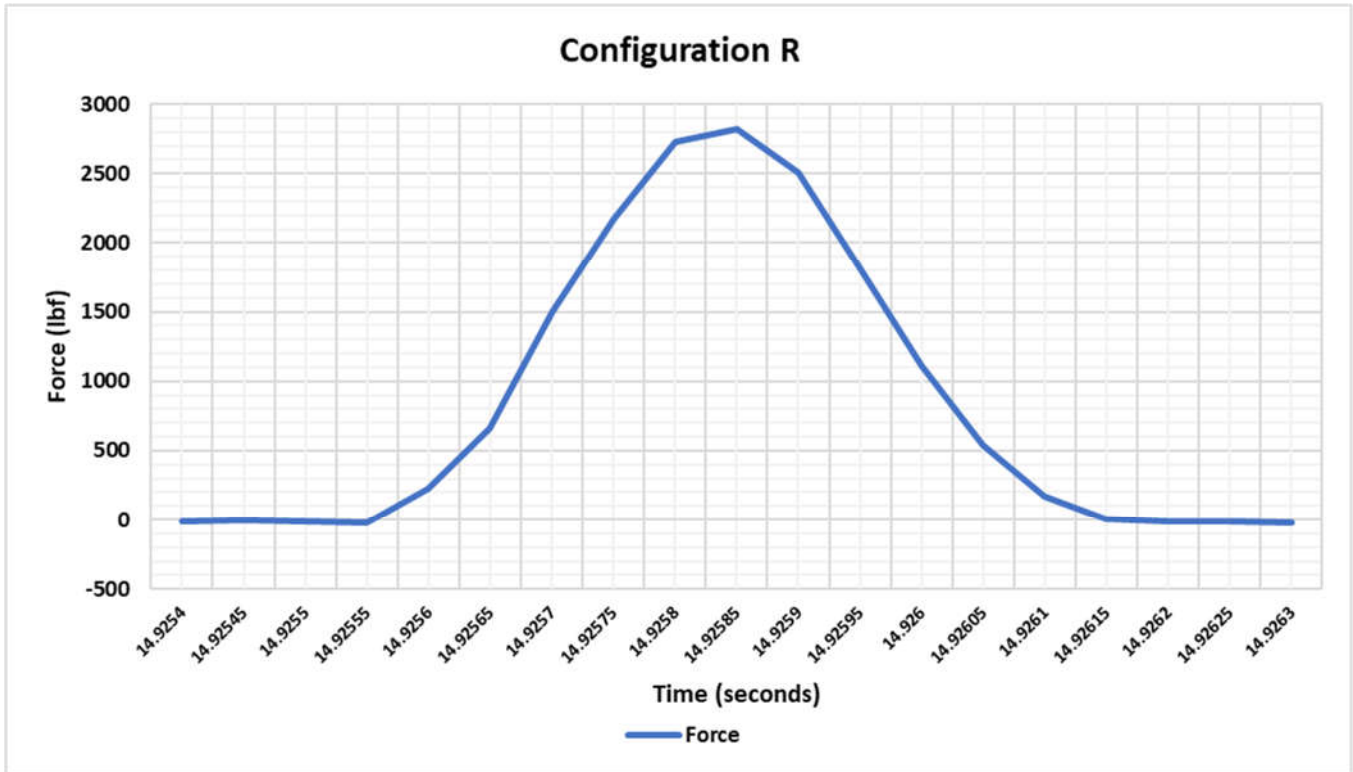
Force Graph



Test Setup Photograph (Orientation R)



Post-test Photograph (Orientation R)



Force Graph