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Report No. 103664303CRT-001

MCB Industries, Inc.

124 N. Broadway, Suite 90
De Pere, WI 54115
USA

Standards

FAA Engineering Brief No 83: In Pavement Light Fixture Bolts, dated 6/2/2010
FAA Adivsory Circular 150/5345-46E: Specification For Runway and Taxiway Light Fixtures, dated 3/2/2016

Test Purpose	Research on SEMS/wedge and Smart Bolts
Test Dates	September 13, 2018 through September 19, 2018

Ryan Siddon
Project Engineer
Lighting

Jeremy N. Downs, P.E.
Staff Engineer
Lighting

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Sample Information					
Date Rec.	Intertek ID	Description	Condition	Model No. / Part No.	Item #
4/4/18	CRT1804041329-002	12" Aluminum Light Fixture Top w/ 3/8" bolt holes - L-852S(L)	Welded Bar - Only Al top used	ADB REL/112	1
9/12/18	CT1809121244-001	10" Class 1A Galvanized Carbon Steel Base Extention with (6) 3/8" threaded holes and (6) larger drilled through holes.	Undamaged	N/A	2
5/1/18	CRT1805011138-002-3	3/4" Class 1A Galvanized Carbon Steel Spacer Ring with (12) 3/8" through holes	Undamaged	N/A	3
5/1/18	CRT1805011138-002-4	1/2" Class 1A Galvanized Carbon Steel Spacer Ring with (12) 3/8" through holes	Undamaged	N/A	4
5/1/18	CRT1805011138-002-5	1/16" Class 1A Galvanized Carbon Steel Spacer Ring with (12) 3/8" through holes	Undamaged	N/A	5
9/13/18	CRT1809131583-001-1	3/8"-16 F593C Hex Bolts - Double Pink Coated - Marked Paw Print- 4.25" length - SEMS Wedge Washer	Undamaged	N/A	6
9/13/18	CRT1809131583-001-2	3/8"-16 F593C Hex Bolts - Pink Purple Coated - Marked Paw Print- 4.25" length - SEMS Wedge Washer	Undamaged	N/A	7
9/14/18	CRT1809141592-001	3/8"-16 F593C (unmarked - claimed by client) Hex "SMART" Bolts - Pink Purple Coated - Marked Paw Print- 4.25" length - SEMS Wedge Washer- Blue Indicator on head	Undamaged	N/A	8

Sample Information

Picture(s)

Item 1

Item 2

Item 3

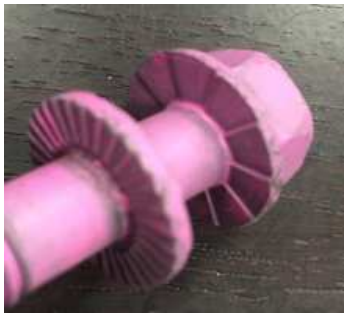
Item 4

Item 5

Sample Information

Item 6

Item 7



Sample Information

Item 8

Test Plan and Datasheets			
Client	MCB Industries, Inc.	Engineer	Ryan Siddon
Report #	103664303CRT-001	Reviewer	Jeremy N. Downs, P.E.
Product	SEMS/wedge and "Smart Bolts"	Model(s)	Various - See sample pg.
Standard	FAA Engineering Brief No 83 FAA Adivsory Circular 150/5345-46E		

Spec	Test name	Test Number	Pass Fail NA
EB83 (#)	Skimore Wilhelm Testing	1	NA
46E (&)	Horizontal Shear Test with Slip Measurement	2	NA
46E (&)	Vibration Testing	3	NA

(#) Note: new proposed standard not yet finalized.
(&) Note: modified testing.

Diameter (in)	Bolt Type	Yield Strength (psi)	Proof Strength (psi)	Tensile Strength (psi)	Stress Areas (in^2)	Yield Load (lbs)	Proof Load (lbs)	75% of Proof or Yield (lbs)	Ultimate Load (lbs)
3/8"	ASTM F593C Grade 304 SS	65,000	NA	100,000 150,000	0.0775	5038	NA	3778	7750 11625

Skidmore Wilhelm Testing

The test bolts were assembled in the Skidmore-Wilhelm Bolt Tension Calibrator with the MCB William System, light base extension sections, and light fixture tops. Other configurations were tested as well. The bolts were then tightened in 5ftlb increments up to 75% of the bolt's proof or yield load as indicated in the applicable standard. The corresponding force versus torque results were recorded, and the friction coefficient was calculated using the below equation. T=K*D*FP

Results of Tests

Testing Configuration:	4.25" length 3/8" F593C Purple-Pink Single Coated SEMS Wedge Bolt Class 1A Galvanized Test Block - Intertek Inventory (slightly used) Aluminum fixture top piece (0.440in ID Bolt Holes) - Intertek Inventory (slightly used)

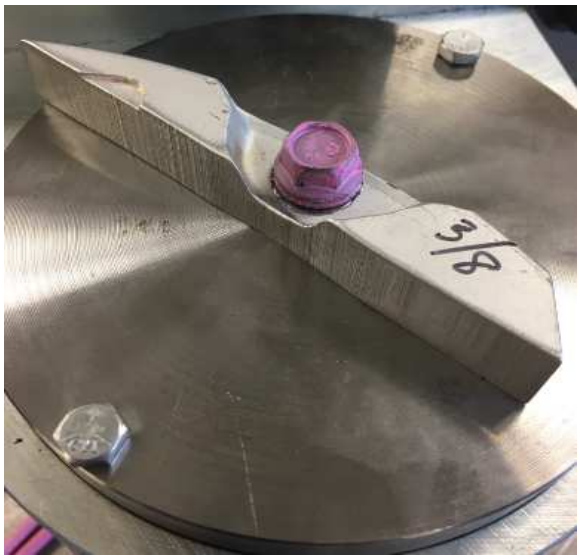
Bolt 1			
Torque	Torque	Tension	
T (in-lbs)	T (ft-lbs)	Fp (lbs)	K
60	5	300	0.533
120	10	600	0.533
180	15	900	0.533
240	20	1200	0.533
300	25	1600	0.500
360	30	2000	0.480
420	35	2400	0.467
480	40	2700	0.474
540	45	3100	0.465
600	50	3100	0.516
660	55	3600	0.489
720	60	3800	0.505
Bolt 1 Average K			0.502

Bolt 2			
Torque	Torque	Tension	
T (in-lbs)	T (ft-lbs)	Fp (lbs)	K
60	5	300	0.533
120	10	600	0.533
180	15	1000	0.480
240	20	1300	0.492
300	25	1600	0.500
360	30	2000	0.480
420	35	2400	0.467
480	40	2800	0.457
540	45	3100	0.465
600	50	3100	0.516
660	55	3500	0.503
720	60	3800	0.505
Bolt 2 Average K			0.494

Bolt 3			
Torque	Torque	Tension	
T (in-lbs)	T (ft-lbs)	Fp (lbs)	K
60	5	300	0.533
120	10	600	0.533
180	15	1000	0.480
240	20	1300	0.492
300	25	1700	0.471
360	30	2100	0.457
420	35	2400	0.467
480	40	2800	0.457
540	45	3200	0.450
600	50	3500	0.457
660	55	3600	0.489
720	60	4200	0.457
Bolt 3 Average K			0.479

Average K	0.492

Test Set-Up



Testing Configuration:	4.25" length 3/8" F593C Pink Double Coated SEMS Wedge Bolt Class 1A Galvanized Test Block - Intertek Inventory (slightly used) Aluminum fixture top piece (0.440in ID Bolt Holes) - Intertek Inventory (slightly used)

Bolt 1			
Torque	Torque	Tension	
T (in-lbs)	T (ft-lbs)	Fp (lbs)	K
60	5	500	0.320
120	10	900	0.356
180	15	1400	0.343
240	20	1900	0.337
300	25	2300	0.348
360	30	2700	0.356
420	35	3200	0.350
480	40	3600	0.356
540	45	3900	0.369
Bolt 1 Average K			0.348

Bolt 2			
Torque	Torque	Tension	
T (in-lbs)	T (ft-lbs)	Fp (lbs)	K
60	5	400	0.400
120	10	900	0.356
180	15	1300	0.369
240	20	1800	0.356
300	25	2200	0.364
360	30	2700	0.356
420	35	3000	0.373
480	40	3500	0.366
540	45	3900	0.369
Bolt 2 Average K			0.368

Bolt 3			
Torque	Torque	Tension	
T (in-lbs)	T (ft-lbs)	Fp (lbs)	K
60	5	400	0.400
120	10	900	0.356
180	15	1300	0.369
240	20	1800	0.356
300	25	2100	0.381
360	30	2400	0.400
420	35	2700	0.415
480	40	3100	0.413
540	45	3500	0.411
600	50	3700	0.432
Bolt 3 Average K			0.393

Average K	0.370

Test Set-Up

Complies: N/A

Tested By:	Ryan Siddon/Jeremy Downs			Signature or initials:	RwS	Comp. Date	9/13/18
Reviewed By:	JND			Signature or initials:	JMD		
Test Equipment Used:	10, 11, 12, 13, 14, 17			Sample No:	Various. See above and sample page.		
Amb (ºC):	24.4	RH%	57				

Testing Configuration:	4.25" length 3/8" F593C Purple-Pink Single Coated SEMS Wedge SMART Bolt Class 1A Galvanized Test Block - Intertek Inventory (slightly used) Aluminum fixture top piece (0.440in ID Bolt Holes) - Intertek Inventory (slightly used)

Bolt 1				
Torque	Torque	Tension		
T (in-lbs)	T (ft-lbs)	Fp (lbs)	K	V*
0	--	--	--	4.123
60	5	300	0.533	3.990
120	10	900	0.356	3.312
180	15	1400	0.343	2.890
240	20	1800	0.356	2.650
300	25	2100	0.381	2.515
360	30	2400	0.400	2.337
420	35	2800	0.400	2.155
480	40	3200	0.400	1.988
Note: good match on blue idicator				
540	45	3500	0.411	--
600	50	3700	0.432	1.850
660	55	4200	0.419	1.761
720	60	4600	0.417	--
780	65	4700	0.443	--
Note: small silver spot in indicator				
840	70	5100	0.439	5.074
Note: full silver ring around indicator				
900	75	5200	0.462	--
960	80	5600	0.457	--
1020	85	6300	0.432	--
Note: extremely dark indicator				
1080	90	6200	0.465	--
1140	95	break	--	--
Bolt 1 Average K @75%			0.401	--

Bolt 2				
Torque	Torque	Tension		
T (in-lbs)	T (ft-lbs)	Fp (lbs)	K	V*
0	--	--	--	4.870
60	5	300	0.533	4.703
120	10	700	0.457	4.183
180	15	1100	0.436	3.740
240	20	1500	0.427	5.074
Note: indicator failed with multimeter				
300	25	2000	0.400	--
360	30	2500	0.384	--
420	35	2700	0.415	--
480	40	3200	0.400	--
540	45	3700	0.389	--
600	50	3900	0.410	--
Note: darker than indicator				
660	55	4300	0.409	--
720	60	4900	0.392	--
780	65	5100	0.408	--
840	70	5300	0.423	--
900	75	5800	0.414	--
960	80	6000	0.427	--
1020	85	6300	0.432	--
1080	90	6300	0.457	--
1140	95	break	--	--
Bolt 2 Average K @ 75%			0.425	--

Bolt 3				
Torque	Torque	Tension		
T (in-lbs)	T (ft-lbs)	Fp (lbs)	K	V*
60	5	200	0.800	3.834
120	10	700	0.457	3.420
180	15	1200	0.400	3.048
240	20	1700	0.376	2.756
300	25	2100	0.381	2.480
360	30	2600	0.369	2.242
420	35	3000	0.373	2.060
480	40	3600	0.356	1.926
Note: good match on blue idicator				
540	45	4100	0.351	1.739
Note: good match on blue idicator				
600	50	4300	0.372	1.706
660	55	4600	0.383	--
720	60	5100	0.376	1.570
780	65	5200	0.400	1.540
Note: darker than indicator				
840	70	5700	0.393	1.503
900	75	5900	0.407	1.486
960	80	6200	0.413	1.459
1020	85	6500	0.418	--
Note: full silver ring around indicator				
1080	90	break	--	--
Bolt 3 Average K @ 75%			0.383	--

Average K @ 75%	0.403

Photo 1

Photo 2

Observations:	Photo 1 - Left bolt head shows no tension applied to bolt Right bolt head shows ultimate tensile stress (failure point) Photo 2 - Strain gauge inside of the bolt after failure

*Note: Voltage (V) was a relative measurement taken with a first party multimeter. This data is not through calibrated equipment through Intertek's quality system

Test Set-Up

Complies: N/A

Tested By:	Ryan Siddon/Jeremy Downs			Signature or initials:	RwS	Comp. Date: 9/14/18
Reviewed By:	JND			Signature or initials:	JND	
Test Equipment Used:	10, 11, 12, 13, 14, 17			Sample No:	Various. See above and sample page.	
Amb (ºC):	24.7	RH%	56			

Testing Configuration:	4.25" length 3/8" F593C Pink Double Coated SEMS Wedge Bolt Class 1A Galvanized Test Block - Intertek Inventory (slightly used) Ductile Iron Ring fixture top piece (0.422in ID Bolt Holes) - Intertek Inventory (slightly used)

Bolt 1			
Torque	Torque	Tension	
T (in-lbs)	T (ft-lbs)	Fp (lbs)	K
60	5	400	0.400
120	10	1300	0.246
180	15	2300	0.209
240	20	3100	0.206
300	25	4100	0.195
Bolt 1 Average K			0.251

Bolt 2			
Torque	Torque	Tension	
T (in-lbs)	T (ft-lbs)	Fp (lbs)	K
60	5	600	0.267
120	10	1400	0.229
180	15	2200	0.218
240	20	3100	0.206
300	25	3900	0.205
Bolt 2 Average K			0.225

Average K	0.238

Test Set-Up

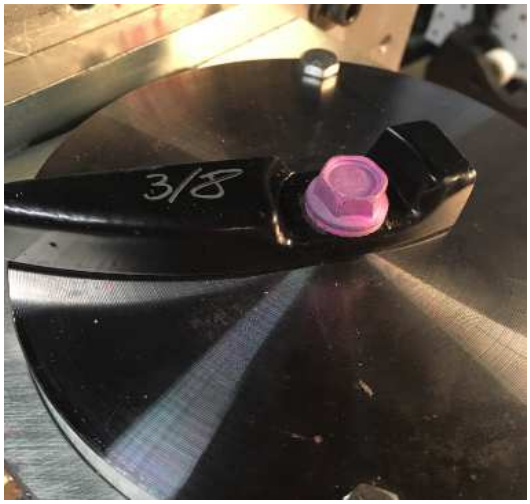
Testing Configuration:	4.25" length 3/8" F593C Purple-Pink Single Coated SEMS Wedge Bolt Class 1A Galvanized Test Block - Intertek Inventory (slightly used) Ductile Iron Ring fixture top piece (0.422in ID Bolt Holes) - Intertek Inventory (slightly used)

Bolt 1			
Torque	Torque	Tension	
T (in-lbs)	T (ft-lbs)	Fp (lbs)	K
60	5	500	0.320
120	10	1200	0.267
180	15	2000	0.240
240	20	2700	0.237
300	25	3500	0.229
360	30	4200	0.229
Bolt 1 Average K			0.253

Bolt 2			
Torque	Torque	Tension	
T (in-lbs)	T (ft-lbs)	Fp (lbs)	K
60	5	500	0.320
120	10	1300	0.246
180	15	2100	0.229
240	20	2800	0.229
300	25	3500	0.229
360	30	4200	0.229
Bolt 2 Average K			0.247

Average K	0.250

Test Set-Up



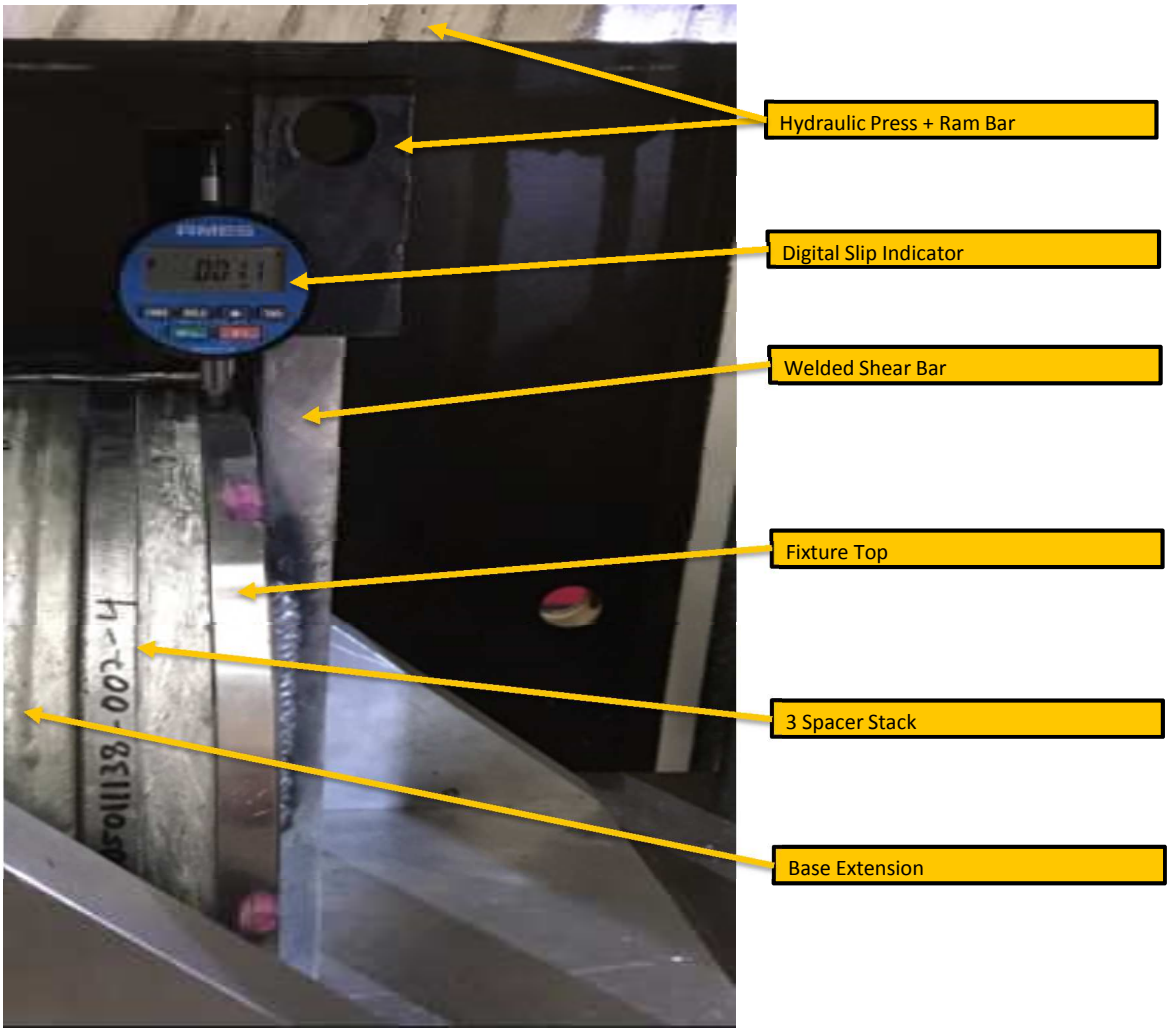
Complies: N/A

Tested By:	Ryan Siddon			Signature or initials:	RwS	Comp. Date	9/19/18
Reviewed By:	JND			Signature or initials:	JND		
Test Equipment Used:	10, 11, 12, 13, 14, 17			Sample No:	Various. See above and sample page.		
Amb (ºC):	23.8	RH%	48.5				

Horizontal Shear Test with Slip Measurement

Horizontal shear tests were performed to simulate the shearing load applied to the top surface of an in pavement fixture by a braking aircraft tire. A bar was welded to the top of the fixtures parallel to the runway centerline and parallel to the ground plane. The light fixture was installed on an L-868B light base extension, and the fixture bolts were torqued to 75% of the yield or proof torque. The shearing load was increased slowly in 500 lb increments until failure or slippage at the joint between the light fixture and light base extension. The light fixture was inspected for any mechanical damage after the test. Slippage of the light fixture was evaluated in the direction of test with respect to the light base extension by the use of a dial indicator. Slippage is considered ≥0.020in in movement (marked in red below).

Test Set Up



Results of Tests

Testing Configuration:	4.25" length 3/8" F593C Pink-Purple Coated SEMS Wedge SMART Bolt 10" Class 1A Galvanized Base Extension Aluminum fixture Top

Pre-Test Torque Values						
Bolts	1	2	3	4	5 (Thr)	6 (Thr)
Bolt torques (in-lbs)	570	570	570	570	570	570

T=D*K*Fp

K	0.403
D	0.375
Fp	3778
T	571

Direction	Aft						
Force (lbs)	500	1000	1500	2000	2500	3000	**3500**
Measured slippage per loading (in)							
Gauge Start (in)	0.0010	0.0010	0.0010	0.0010	-0.0010	-0.0060	-0.0120
Gauge End (in)	0.0010	0.0010	0.0010	-0.0010	-0.0060	-0.0120	-0.0200
Slippage (in)	0.0000	0.0000	0.0000	0.0020	0.0050	0.0060	0.0080
Total Slippage (in)	0.0000	0.0000	0.0000	0.0020	0.0070	0.0130	**0.0210**

Force (lbs)	4000	4500	5000	5500	6000	6500	7000
Measured slippage per loading (in)							
Gauge Start (in)	-0.0200	-0.0270	-0.0340	--	--	--	--
Gauge End (in)	-0.0270	-0.0340	-0.0410	--	--	--	--
Slippage (in)	0.0070	0.0070	0.0070	--	--	--	--
Total Slippage (in)	0.0280	0.0350	0.0420	--	--	--	--

F=μFn

F	Fn	μ
3500	22668	0.15

Post-Test Torque Values						
Bolts	1	2	3	4	5 (Thr)	6 (Thr)
Bolt torques (in-lbs)	N/A	N/A	N/A	N/A	N/A	N/A

Observations:	Testing to failure: System completely failed at 29,500lb See failure photos below: Photo 1 - Six sheared bolts in can Photo 2 - Some bolt heads returned to normal untorqued color while some stayed in torqued color

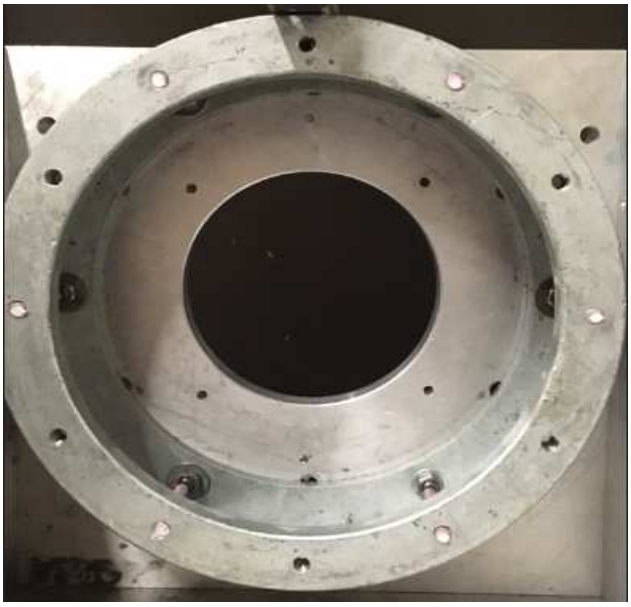


Photo 1

Photo 2

Complies: N/A

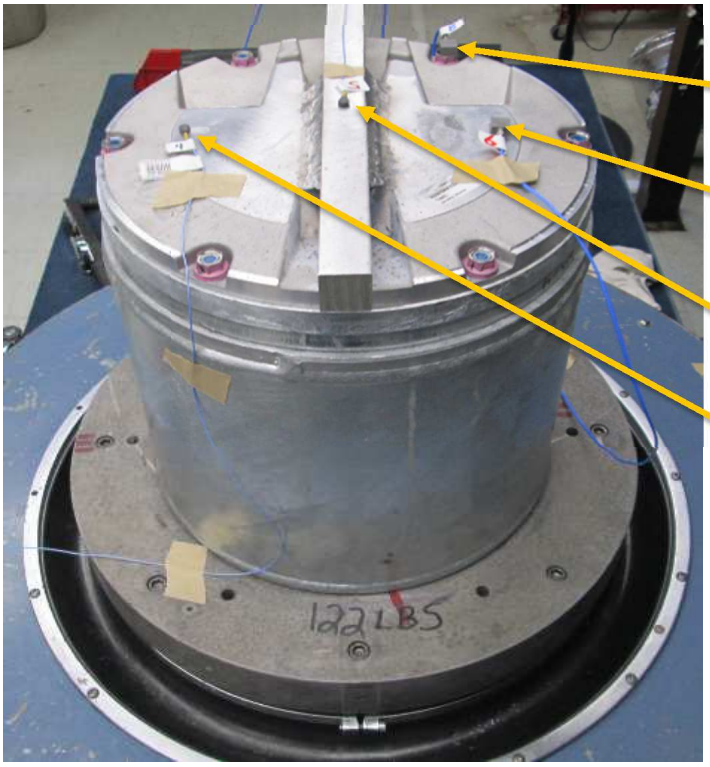
Tested By:	Ryan Siddon/Jeremy Downs			Signature or initials:	RWS	Comp. Date	9/14/18
Reviewed By:	JND			Signature or initials:	JND		
Test Equipment Used:	10, 12, 14, 15, 16, 17			Sample No:	Various. See above and sample page.		
Amb (ºC):	25.2	RH%	61.4				

Vibration
The light fixture was installed on an L-868B light base extension with the appropriate spacer rings, and the fixture bolts were torqued to 75% of the failure torque. The assembly was subjected to a sinusoidal vibration along three mutually perpendicular axes. The assembly was vibrated over a frequency range of 20 to 500 Hz, with a maximum acceleration of 10 Gs for 10 minutes. Then the assembly was vibrated from 500 to 2000 Hz, with a maximum acceleration of 15 Gs for 10 minutes. After the test, the assembly was inspected for mechanical failure, loosening of any part, or displacement of any part. The torque of each bolt was measured after the test.
Test Set-Up

Vertical	Up and Down - Z Axis
Horiz	Fixture Perpendicular to Runway (table movement) - Y Axis
Lateral	Fixture Parallel to Runway (table movement) - X Axis

Test Set-Up
Accelerometers To Fixture and Bolts (numbers may vary by test - see testing notes for each run)

Vertical Set-Up



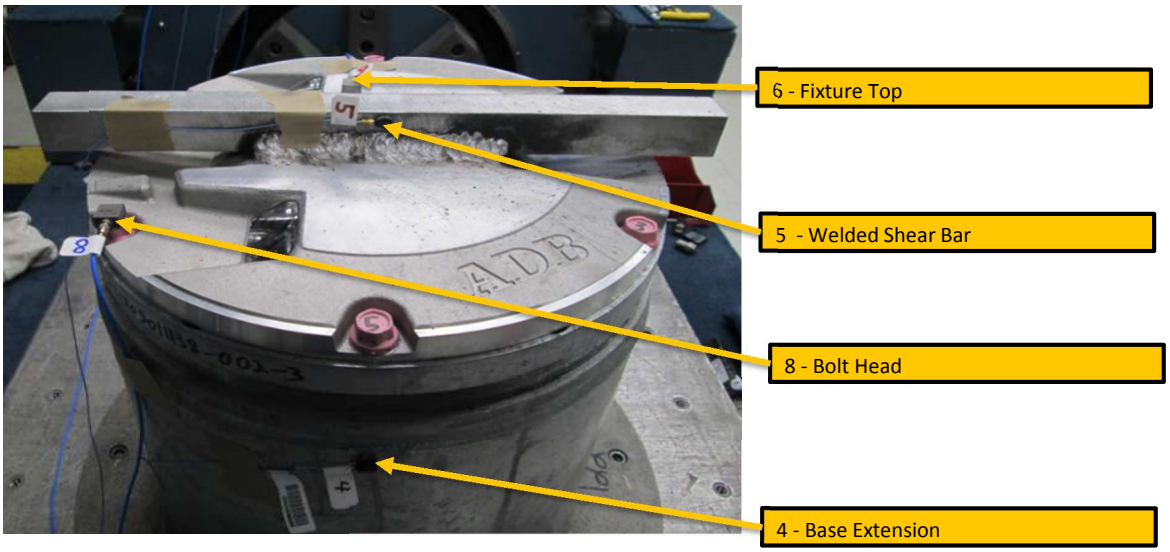
8 - Bolt Head

6 - Fixture Top

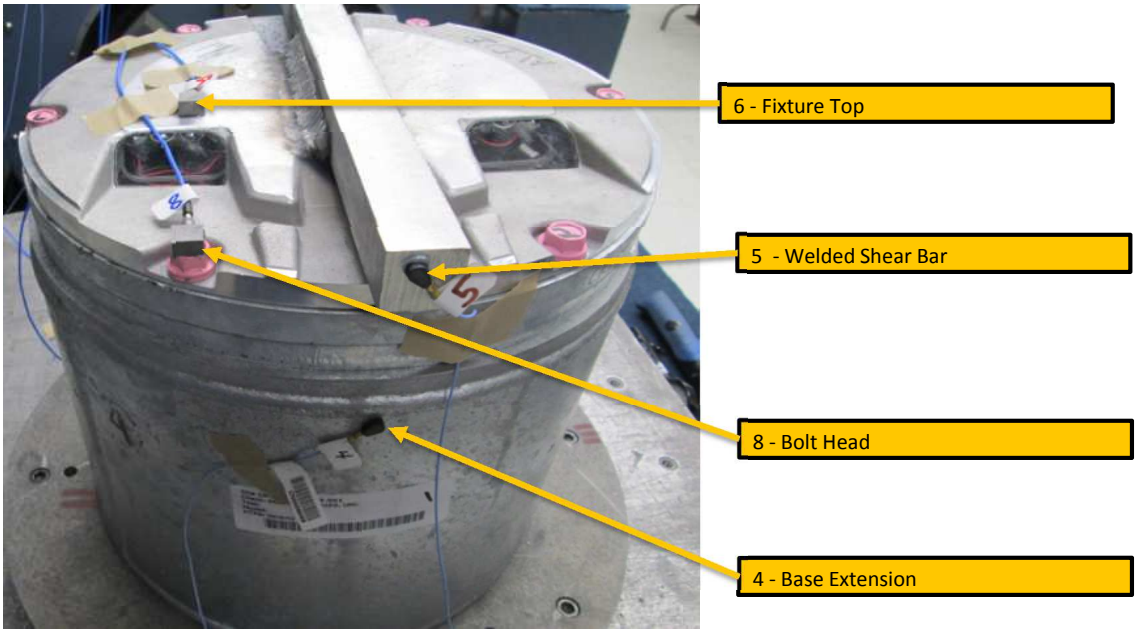
5 - Welded Shear Bar

4 - Fixture Top

Horizontal Set-Up



Lateral Set-Up



Results of Tests

Testing Configuration:	4.25" length 3/8" F593C Pink Coated SEMS Wedge Bolt 10" Class 1A Galvanized Base Extension Aluminum Fixture Top
Testing Notes:	Channel 8 - Bolt Channel 4, 5, 6 - Test Controls (averaged) - See photos above for specific components

Pre-Test Torque Values						
Bolts	1	2	3	4	5	6
Bolt torques (in-lbs)	530	530	530	530	530	530

T=D*K*Fp

K	0.370
D	0.375
Fp	3778
T	524

Test 3 - Vertical - 15G						
Post-Test Torque Values						
Bolts	1	2	3	4	5	6
Bolt torques (in-lbs)	520	530	530	520	520	530

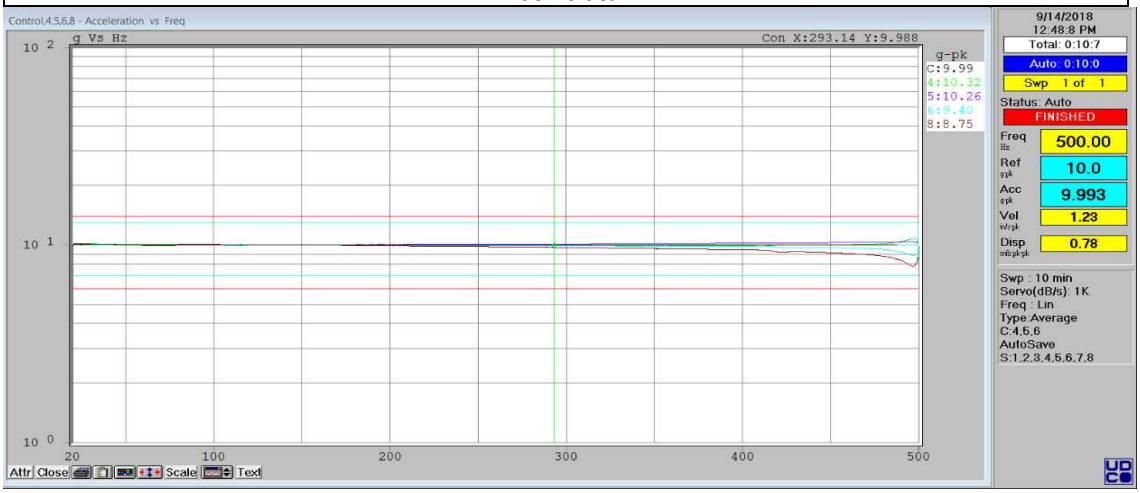
Test 2 - Horizontal - 15G						
Post-Test Torque Values						
Bolts	1	2	3	4	5	6
Bolt torques (in-lbs)	490	520	510	510	510	530

Test 1 - Lateral - 15G						
Post-Test Torque Values						
Bolts	1	2	3	4	5	6
Bolt torques (in-lbs)	450	490	510	520	470	510

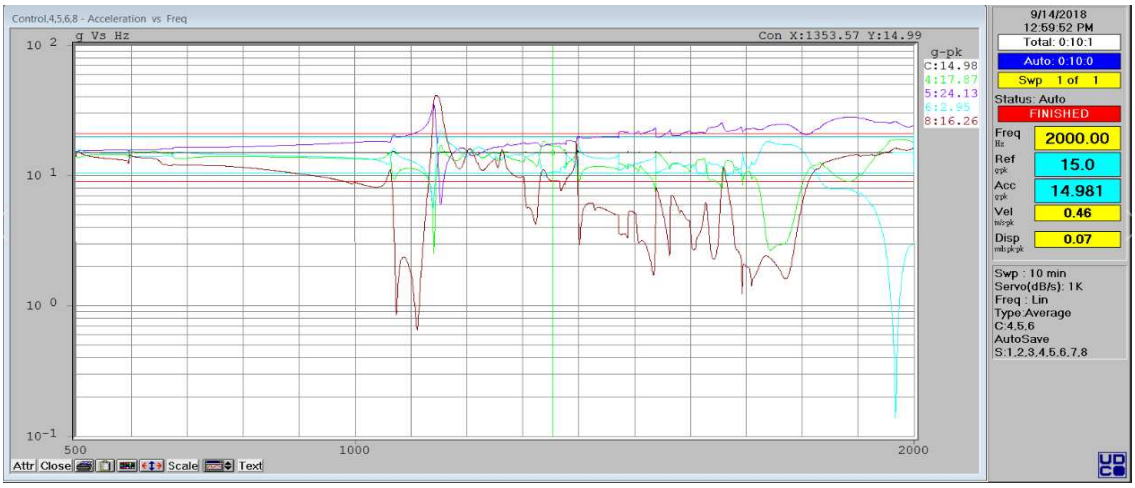
Observations:	N/A

Plots

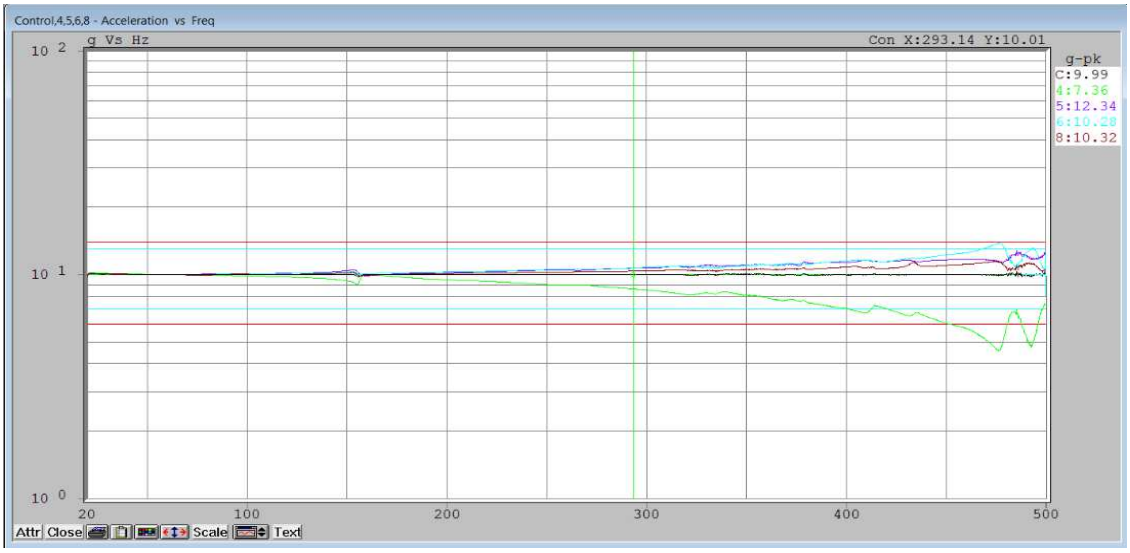
10G Vertical



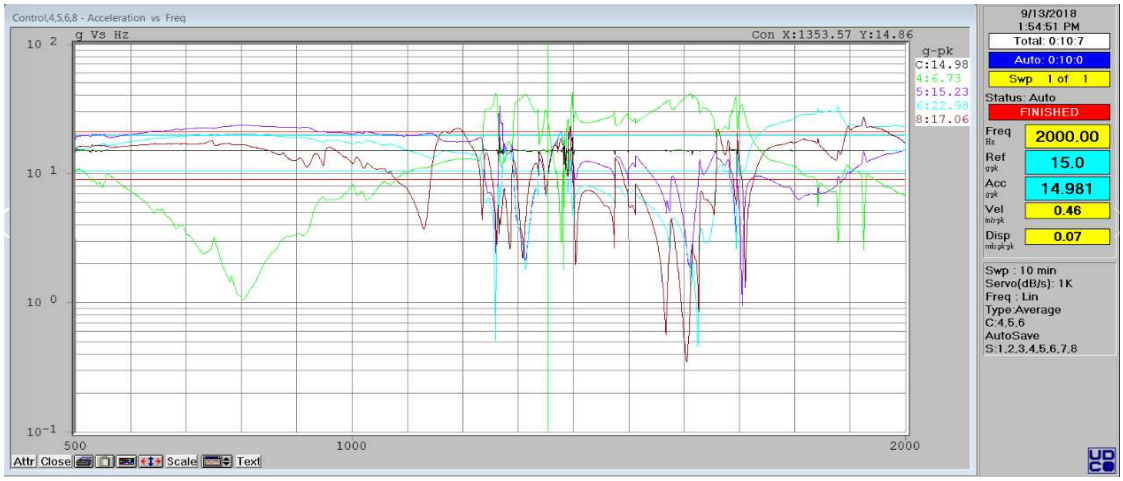
15G Vertical



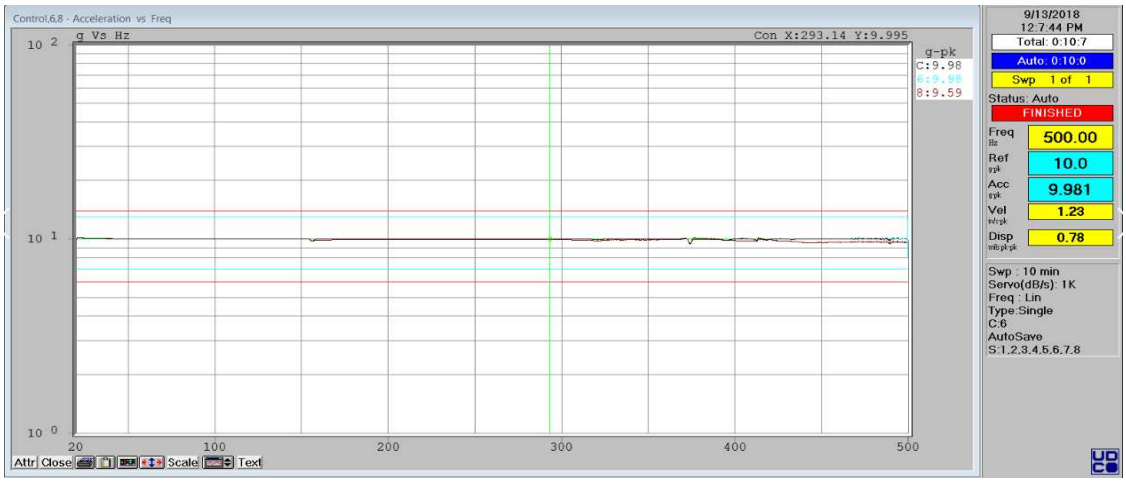
10G Horizontal



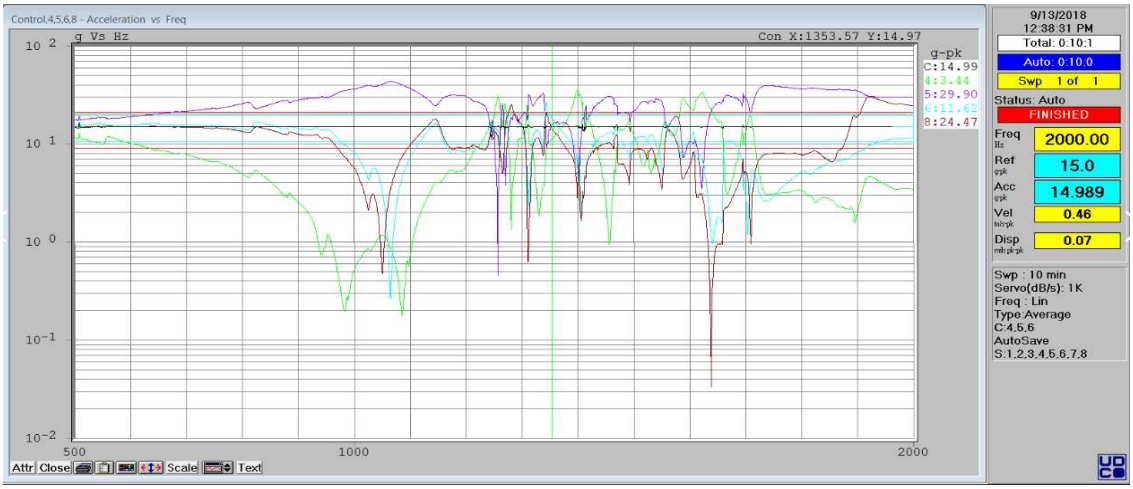
15G Horizontal



10G Lateral



15G Lateral



Complies: N/A

Tested By:	Gordon West / Ryan Siddon			Signature or initials:	RWS	Comp. Date	9/14/18
Reviewed By:	JND			Signature or initials:	JND		
Test Equipment Used:	1,2,3,4,5,6,7,8,9,10			Sample No:	Various. See above and sample page.		
Amb (ºC):	23	RH%	53				

Testing Configuration:	4.25" length 3/8" F593C Pink-Purple Coated SEMS Wedge SMART Bolt 10" Class 1A Galvanized Base Extension Aluminum Fixture Top

Testing Notes:	Channel 8 - Bolt Channel 4, 5, 6 - Test Controls (averaged) - See photos above for specific components # and number next to bolt numbers 1-6 are the serial numbers for each bolt

Pre-Test Torque Values						
Bolts	1 (#009)	2 (#022)	3 (#010)	4 (#015)	5 (#020)	6 (#014)
Bolt torques (in-lbs)	570	570	570	570	570	570
Color Match? (Y/N)	Y	Y	Y	Y	Y	Y

T=D*K*Fp

K	0.403
D	0.375
Fp	3778
T	571

Test 3 - Vertical - 15G						
Post-Test Torque Values						
Bolts	1 (#009)	2 (#022)	3 (#010)	4 (#015)	5 (#020)	6 (#014)
Bolt torques (in-lbs)	530	570	570	450	550	560
Color Match? (Y/N)	Y	Y *	Y	Y	Y %	Y

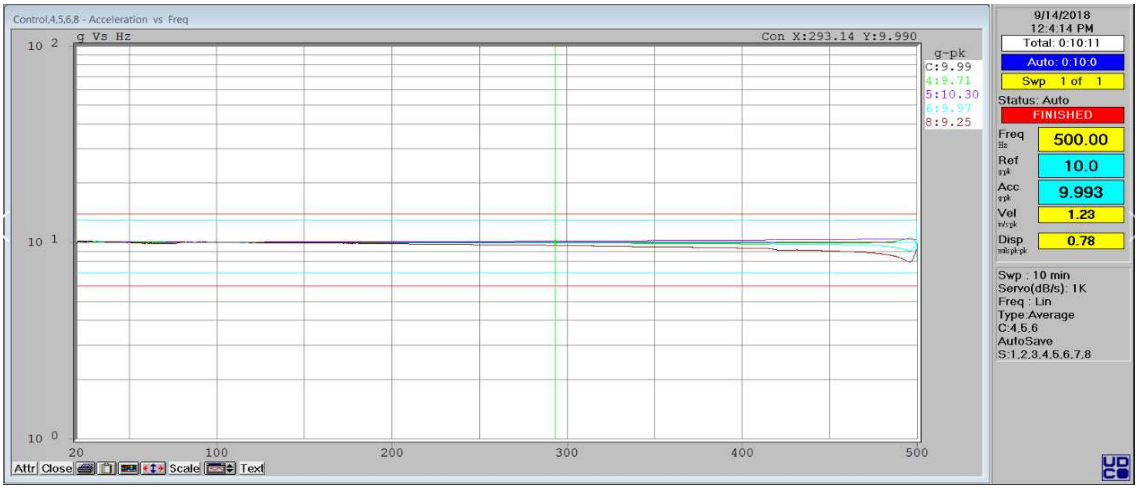
Test 2 - Horizontal - 15G						
Post-Test Torque Values						
Bolts	1 (#009)	2 (#022)	3 (#010)	4 (#015)	5 (#020)	6 (#014)
Bolt torques (in-lbs)	540	560	570	570	550	570
Color Match? (Y/N)	Y	Y *	Y	Y	Y	Y

Test 1 - Lateral - 15G						
Post-Test Torque Values						
Bolts	1 (#009)	2 (#022)	3 (#010)	4 (#015)	5 (#020)	6 (#014)
Bolt torques (in-lbs)	570	500	550	570	560	560
Color Match? (Y/N)	Y	Y *	Y	Y	Y	Y

Observations:	% Small amount of silver in the indicator instead of blue after vertical (third test) * Small amount of distortion in the indicator after lateral (first test

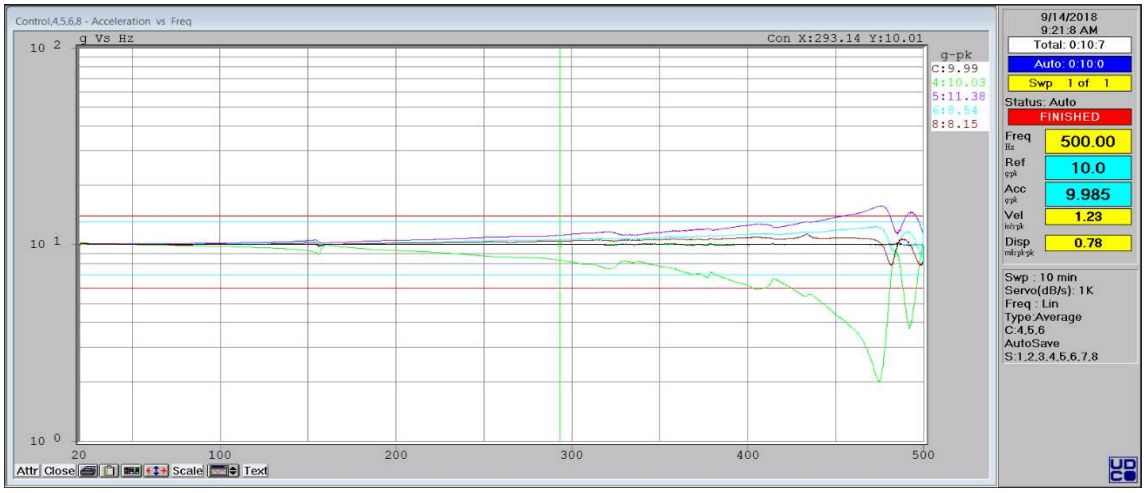
Plots

10G Vertical

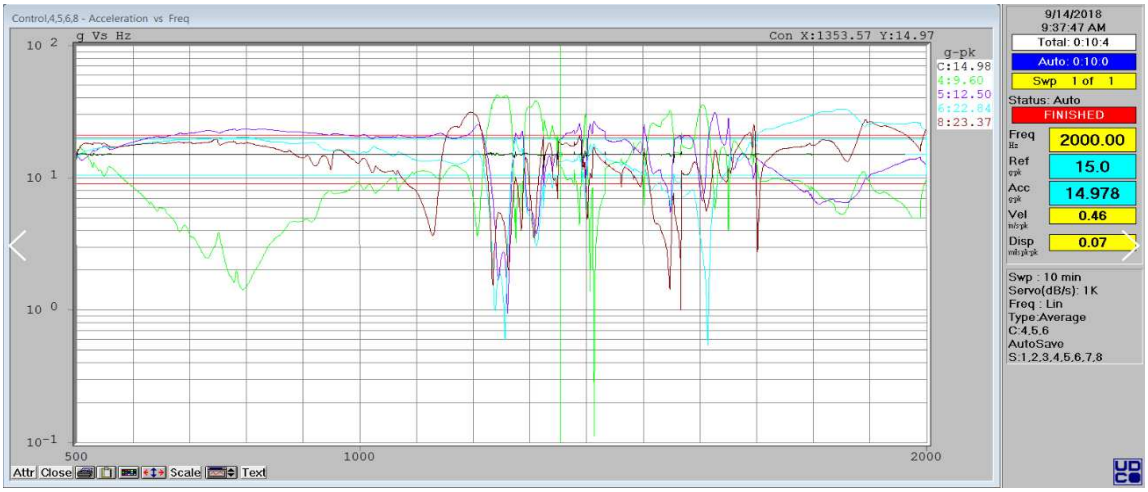


15G Vertical

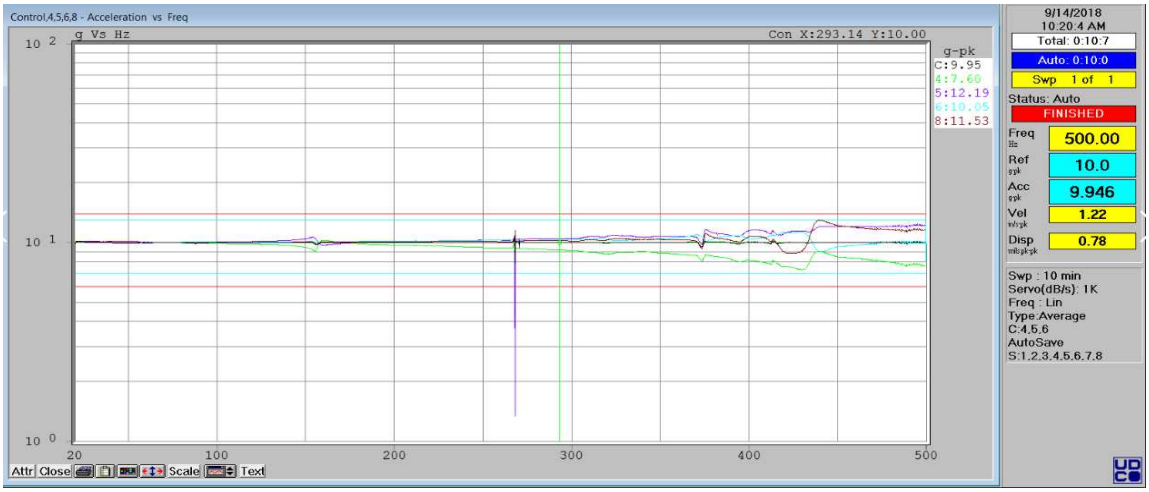
10G Horizontal



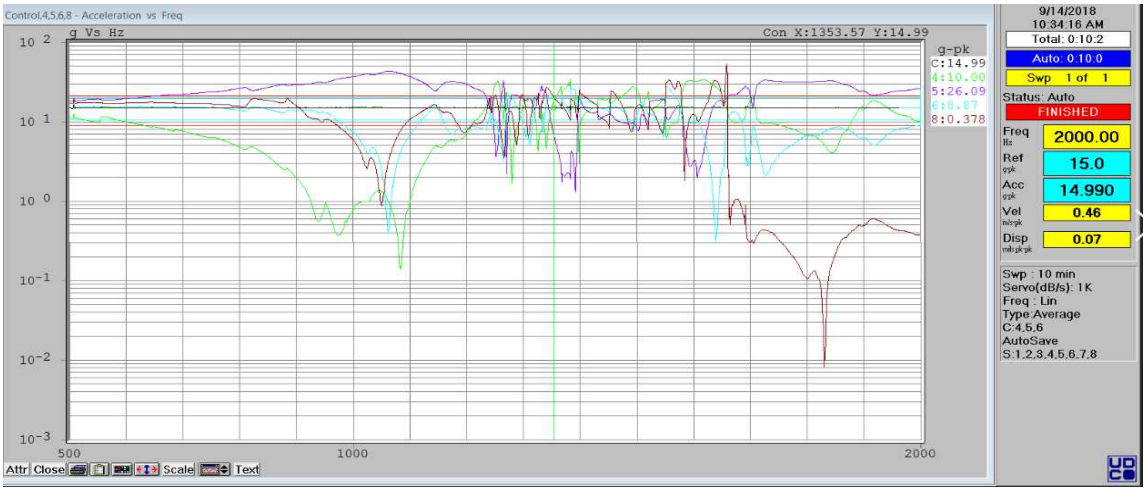
15G Horizontal



10G Lateral



15G Lateral



Complies: N/A

Tested By:	Gordon West / Ryan Siddon			Signature or initials:	RWS	Comp. Date	9/14/18
Reviewed By:	JND			Signature or initials:	JND		
Test Equipment Used:	1,2,3,4,5,6,7,8,9,10			Sample No:	Various. See above and sample page.		
Amb (ºC):	23	RH%	54				

Equipment list

#	Intertek ID No.	Description	Manufacturer	Calibration Due
1	N1456	Torque Wrench	Westward	15-Feb-2019
2	M281	Digital Hygro-Thermometer	Testo	18-Apr-2019
3	V252	Signal Conditioner	Unholtz-Dickie	13-Jul-2019
4	V272	Signal Conditioner	Unholtz-Dickie	16-Jul-2019
5	V393	Vibration Controler	Unholtz-Dickie	16-Jul-2019
6	M299	Accelerometer	PCB Piezotronics	22-Feb-2019
7	M298	Accelerometer	PCB Piezotronics	22-Feb-2019
8	V334	Accelerometer	PCB Piezotronics	23-Feb-2019
9	M284	Accelerometer	PCB Piezotronics	20-Aug-2019
10	M278	Dial Torque Wrench	CDI Torque Products Inc.	04-Jan-2019
11	M279	Digital Torqe Wrench	Imada	17-Nov-2018
12	M274	Hygrothermometer	Extech	03-Nov-2018
13	M280	Bolt Tension Calibrator	Skidmore Wilhelm	22-Nov-2018
14	M283	Digital Calipers	Mitutoyo	21-Apr-2019
15	S108	Press	Tinius Olsen	01-May-2019
16	N1266	Digital Indicator	B.C. Ames Co.	18-Jan-2019
17	M282	Digital Hygro-Thermometer	Testo	18-Apr-2019

Note: For measurement uncertainty, refer to the calibration certificates for all test equipment.