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Report No. 103473607CRT-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 Advisory Circular 150/5345-46E: Specification For Runway and Taxiway Light Fixtures, dated 3/2/2016

<i>Test Purpose</i>	Research on configurations of bolt, spacer rings, and base extensions for In Pavement Fixtures.
<i>Test Dates</i>	May 3, 2018 through May 7, 2018



Ryan Siddon
Project Engineer
Lighting



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

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Test Plan and Datasheets			
Client	MCB Industries, Inc.	Engineer	Ryan Siddon
Report #	103473607CRT-001	Reviewer	Jeremy N. Downs, P.E.
Product	William System + Other Configurations	Model(s)	Various - See sample pg.
Standard	FAA Engineering Brief No 83 FAA Advisory Circular 150/5345-46E		

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

(#) Note: Standard used as guidance only.

(&) Note: Standard used as guidance only. Modified testing to determine slip coefficients.

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"	SAE J429 Grade 2 CS (Coated)	NA	55,000	74,000	0.0775	NA	4263	3197	5735
3/8"	SAE J429 Grade 5 CS (Coated)	NA	85,000	120,000	0.0775	NA	6588	4941	9300
3/8"	ASTM F593C Grade 304 SS	65,000	NA	100,000 150,000	0.0775	5038	NA	3778	7750 11625
3/8"	Super Bolt (\$)	150,000	NA	180,000	0.0775	11625	NA	8719	13950

(\$ Note: claimed by MCB.

Sample Information					
Date Rec.	Intertek ID	Description	Condition	Model No. / Part No.	Item #
4/4/18	CRT1804041329-001	12" Aluminum Light Fixture Top w/ 3/8" bolt holes - L-852A(L)	Welded Bar - Only Al top used	ADB ITCF-L	1
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	2
5/1/18	CRT1805011138-003-1	3/8"-16 F593C Hex Bolts - Blue Coated - Marked with THE - 4" length - Disc Lock Washer included	Undamaged	F593C-2416x4.00-EZ	3
5/1/18	CRT1805011138-003-2	3/8"-16 Grade 2 Hex Bolts - Orange Coated - Marked with L - 4" length - Disc Lock Washer included	Undamaged	LSO2-2416x4.00-EZ	4
5/1/18	CRT1805011138-003-3	3/8"-16 F593C (claimed by client-unmarked) Flat Head Bevelled Bolts - Blue Coated - 3.75" length - Allen Head fastened.	Undamaged	N/A	5
5/1/18	CRT1805011138-003-4	3/8"-16 F593C (claimed by client-unmarked) Flat Head Bevelled Bolts - Non Coated - 3.75" length - Allen Head fastened.	Undamaged	N/A	6
5/1/18	CRT1805011138-003-5	3/8"-16 Shouldered Head SUPER Bolts - Blue Coated - 3" length - partially threaded - 7/16" head.	Undamaged	N/A	7
5/1/18	CRT1805011138-003-9	3/8"-16 Grade 5 Hex Bolts - Zinc Plated - Marked with NDF - 4" length	Undamaged	N/A	8
5/1/18	CRT1805011138-003-10	3/8"-16 Isabel F593C Shoulder Head Bolts w/ clips and Sprial Lock Flange Nut - Marked with Paw Print- Non Coated - 4" length	Undamaged	N/A	9
5/1/18	CRT1805011138-003-6	Extra Disc Lock Washers found on items 3 and 4	Undamaged	N/A	10
5/1/18	CRT1805011138-003-7	Separate Two Part Lock Washers	Undamaged	Unknown Brand	11
5/1/18	CRT1805011138-003-8	3/8" F594G Spiral Lock Flange Nuts - Marked with SPL - found on item 8	Undamaged	N/A	12
5/1/18	CRT1805011138-001-1	4" High Friction Textured Raw Steel Base Extension with (12) 3/8" bolt holes	Undamaged	N/A	13
5/1/18	CRT1805011138-001-2	3/4" High Friction Textured Raw Steel Spacer Ring with (12) 3/8" through holes	Undamaged	N/A	14
5/1/18	CRT1805011138-001-3	1/2" High Friction Textured Raw Steel Spacer Ring with (12) 3/8" through holes	Undamaged	N/A	15
5/1/18	CRT1805011138-001-4 CRT1805011138-001-5 CRT1805011138-001-6	1/16" High Friction Textured Raw Steel Spacer Ring with (12) 3/8" through holes	Undamaged	N/A	16
5/1/18	CRT1805011138-001-7	1/4" High Friction Textured Raw Steel Spacer Ring with (12) 3/8" through holes and (6) recessed clip slots	Undamaged	N/A	17

Sample Information					
5/1/18	CRT1805011138-001-8	1/4" High Friction Textured Raw Steel Spacer Ring with (6) 3/8" through holes and(6) recessed clip slots	Undamaged	N/A	18
5/1/18	CRT1805011138-002-1	4" Class 1A Galvanized Carbon Steel Base Extension with (12) 3/8" bolt holes	Undamaged	N/A	19
5/1/18	CRT1805011138-002-2	3/4" Class 1A Galvanized Carbon Steel Spacer Ring with (6) 3/8" through holes and (6) recessed clip slots	Undamaged	N/A	20
5/1/18	CRT1805011138-002-3	3/4" Class 1A Galvanized Carbon Steel Spacer Ring with (12) 3/8" through holes	Undamaged	N/A	21
5/1/18	CRT1805011138-002-4	1/2" Class 1A Galvanized Carbon Steel Spacer Ring with (12) 3/8" through holes	Undamaged	N/A	22
5/1/18	CRT1805011138-002-5	1/16" Class 1A Galvanized Carbon Steel Spacer Ring with (12) 3/8" through holes	Undamaged	N/A	23
5/1/18	CRT1805011138-002-6	1/4" Class 1A Galvanized Carbon Steel Spacer Ring with (12) 3/8" through holes and (6) recessed clip slots	Undamaged	N/A	24
5/3/18	N/A	Custom Skidmore Wilhelm simulated 3/4" Base Flange Test Pieces	Undamaged	N/A	25
5/3/18	N/A	Custom Skidmore Wilhelm simulated Isabelle Spiral Lock Test Pieces - found in item 12	Cut	N/A	26
5/3/18	N/A	4" High Friction Textured Raw Steel Base Extension with (12) 3/8" bolt holes	Cut	N/A	27
5/3/18	N/A	Custom Skidmore Wilhelm simulated Auminum Fixture Top Test Piece	Cut	N/A	28
5/4/18	CRT1805041149-001	3/8"-16 Purplish/Blue Isabel F593C (claimed by client-unmarked) - Non Coated Shoulder Head Bolts w/ clips and Sprial Lock Flange Nut - 4" length	Undamaged	N/A	29

Sample Information

Picture(s)

Item 1



Item 2



Item 3



Sample Information

Item 4



Item 5



Item 6



Item 7



Sample Information

Item 8



Item 9



Item 10



Item 11



Item 12



Item 13



Sample Information

Item 14



Item 15



Item 16



Item 17



Item 18



Item 19



Item 20



Item 21



Sample Information

Item 22



Item 23



Item 24



Item 25



Item 26



Item 27



Item 28



Item 29



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" blue coated F593C (washer type mentioned in data below) 3/4" + 1/2" + 1/16" rough textured spacer rings 3/4" custom base flange simulation test piece Aluminum fixture top - bolt through non threaded hole
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Bolt 1 - disc lock washer			
Torque	Torque	Tension	K
T (in-lbs)	T (ft-lbs)	Fp (lbs)	
60	5	500	0.320
120	10	1200	0.267
180	15	1800	0.267
240	20	2400	0.267
300	25	2700	0.296
360	30	3100	0.310
420	35	3200	0.350
480	40	3900	0.328
540	45	--	--
Bolt 1 Average K			0.301

Bolt 2 - disc lock washer			
Torque	Torque	Tension	K
T (in-lbs)	T (ft-lbs)	Fp (lbs)	
60	5	400	0.400
120	10	1200	0.267
180	15	1900	0.253
240	20	2400	0.267
300	25	2800	0.286
360	30	3000	0.320
420	35	3200	0.350
480	40	3400	0.376
540	45	3600	0.400
Bolt 2 Average K			0.324

Bolt 1 and 2 Average K	0.312
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Bolt 3 - two part locking washer			
Torque	Torque	Tension	K
T (in-lbs)	T (ft-lbs)	Fp (lbs)	
60	5	500	0.320
120	10	1400	0.229
180	15	2300	0.209
240	20	3100	0.206
300	25	3900	0.205
Bolt 3 Average K			0.234

Testing Configuration:	4" blue coated F593C (washer type mentioned in data below) no spacer rings 3/4" custom base flange simulation test piece Aluminum fixture top cut out piece - bolt through non threaded hole
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Bolt 1 - disc lock washer			
Torque	Torque	Tension	
T (in-lbs)	T (ft-lbs)	Fp (lbs)	K
60	5	600	0.267
120	10	1300	0.246
180	15	1900	0.253
240	20	2300	0.278
300	25	2600	0.308
360	30	2900	0.331
420	35	3200	0.350
480	40	3200	0.400
Bolt 1 Average K			0.304

Bolt 2 - two part locking washer			
Torque	Torque	Tension	
T (in-lbs)	T (ft-lbs)	Fp (lbs)	K
60	5	700	0.229
120	10	1700	0.188
180	15	2600	0.185
240	20	3500	0.183
300	25	4300	0.186
360	30	--	--
420	35	--	--
480	40	--	--
Bolt 2 Average K			0.194

Testing Configuration:	4" blue coated F593C flanged head - no washer 3/4" + 1/2" + 1/16" rough textured spacer rings Isabel Spiral Lock Nut custom simulation test piece Aluminum fixture top - bolt through non threaded hole
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Bolt 1 - new paw print head marking			
Torque	Torque	Tension	
T (in-lbs)	T (ft-lbs)	Fp (lbs)	K
60	5	200	0.800
120	10	400	0.800
180	15	700	0.686
240	20	1100	0.582
300	25	1400	0.571
360	30	1600	0.600
420	35	1900	0.589
480	40	2100	0.610
540	45	2300	0.626
700	58.3	2400	0.778
750	62.5	2700	0.741
920	76.7	2800	0.876
1060	88.3	2600	1.087
Bolt 1 Average K			0.719

Bolt 2 - new paw print head marking			
Torque	Torque	Tension	
T (in-lbs)	T (ft-lbs)	Fp (lbs)	K
60	5	200	0.800
120	10	500	0.640
180	15	800	0.600
240	20	1200	0.533
300	25	1600	0.500
360	30	1900	0.505
420	35	2100	0.533
480	40	2300	0.557
540	45	2400	0.600
600	50	2400	0.667
700	58.3	2500	0.747
738	61.5	2600	0.757
790	65.8	2600	0.810
Bolt 2 Average K			0.635

Bolt 1 and 2 Average K	0.677
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Bolt 3 - old bolt w/ no head marking*			
Torque	Torque	Tension	
T (in-lbs)	T (ft-lbs)	Fp (lbs)	K
60	5	300	0.533
120	10	800	0.400
180	15	1200	0.400
240	20	1700	0.376
300	25	2100	0.381
360	30	2500	0.384
420	35	2900	0.386
480	40	3200	0.400
540	45	3700	0.389
Bolt 3 Average K			0.406

*Sample from report 103006268CRT-001

Testing Configuration:	3" blue coated SUPER bolt - no washer 3/4" + 1/4" rough textured spacer ring Grade 8 nut custom simulation test piece Aluminum fixture top cut out piece
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Bolt 1			
Torque	Torque	Tension	
T (in-lbs)	T (ft-lbs)	Fp (lbs)	K
60	5	700	0.229
120	10	1400	0.229
180	15	1900	0.253
240	20	2700	0.237
300	25	3200	0.250
360	30	3700	0.259
420	35	4300	0.260
480	40	4900	0.261
540	45	5500	0.262
614	51.2	5600	0.292
630	52.5	5800	0.290
686	57.2	6200	0.295
752	62.7	6700	0.299
758	63.2	7400	0.273
894	74.5	7500	0.318
916	76.3	7900	0.309
1056	88.0	8500	0.331
986	82.2	9000	0.292
Bolt 1 Average K			0.274

Bolt 2			
Torque	Torque	Tension	
T (in-lbs)	T (ft-lbs)	Fp (lbs)	K
60	5	400	0.400
120	10	1400	0.229
180	15	2100	0.229
240	20	2600	0.246
300	25	3100	0.258
360	30	3500	0.274
420	35	4000	0.280
480	40	4400	0.291
540	45	4700	0.306
624	52.0	5200	0.320
668	55.7	5500	0.324
718	59.8	5800	0.330
906	75.5	6300	0.383
952	79.3	6600	0.385
1048	87.3	7100	0.394
1128	94.0	7500	0.401
1206	100.5	7800	0.412
1236	103.0	8000	0.412
Bolt 2 Average K			0.322

Bolt 1 and 2 Average K	0.298
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Red values not used in average calculation
 (not seated fully)

Tested By:	Ryan Siddon, Jeremy Downs	Signature or initials:	RWS — JND	Comp. Date	5/3/18
Reviewed By:	JND	Signature or initials:			
Test Equipment Used:	1, 2, 3, 4, 5	Sample No:	Various. See above and sample page.		
Amb (°C):	23.6	RH%	50		

Testing Configuration:	3.75" blue coated flat head bevelled F593C (no washer) 3/4" Class 1A galvanized spacer ring w/ countersunk through holes 1/2" + 1/16" Class 1A galvanized spacer rings Isabel Spiral Lock Nut custom simulation test piece Aluminum fixture top - bolt through non threaded hole
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Bolt 1			
Torque	Torque	Tension	
T (in-lbs)	T (ft-lbs)	Fp (lbs)	K
60	5	400	0.400
120	10	1000	0.320
180	15	1400	0.343
240	20	1900	0.337
300	25	2300	0.348
360	30	2700	0.356
420	35	3000	0.373
480	40	3200	0.400
540	45	3200	0.450
Bolt 1 Average K			0.351

Bolt 2			
Torque	Torque	Tension	
T (in-lbs)	T (ft-lbs)	Fp (lbs)	K
60	5	200	0.800
120	10	700	0.457
180	15	1100	0.436
240	20	1500	0.427
300	25	1900	0.421
360	30	2200	0.436
420	35	2400	0.467
480	40	2700	0.474
540	45	2900	0.497
Bolt 2 Average K			0.441

Bolt 3			
Torque	Torque	Tension	
T (in-lbs)	T (ft-lbs)	Fp (lbs)	K
60	5	200	0.800
120	10	700	0.457
180	15	1000	0.480
240	20	1500	0.427
300	25	1900	0.421
360	30	2200	0.436
420	35	2500	0.448
Bolt 3 average K			0.445

Red values not used in average calculation. Stopped at approximately 2500lbs clamping force due to socket failures.

5ft-lbs on Bolt 2 not seated fully.

Bolt 1, 2, and 3 Average K	0.412
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Testing Configuration:	4" Isabel with no head marking, lighter purple/blue colored F593C (no washer) 3/4" rough textured spacer ring w/ countersunk through holes 1/2" + 1/4" rough textured spacer rings Isabel Spiral Lock Nut custom simulation test piece Aluminum fixture top - bolt through non threaded hole
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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	1800	0.356
300	25	2200	0.364
360	30	2600	0.369
420	35	2900	0.386
480	40	3200	0.400
540	45	3600	0.400
Bolt 1 Average K			0.366

Bolt 2			
Torque	Torque	Tension	
T (in-lbs)	T (ft-lbs)	Fp (lbs)	K
60	5	500	0.320
120	10	1100	0.291
180	15	1600	0.300
240	20	2200	0.291
300	25	2800	0.286
360	30	3600	0.267
420	35	4800	0.233
480	40	--	--
540	45	--	--
Bolt 2 Average K			0.284

Bolt 1 and 2 Average K	0.325
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Testing Configuration:	4" Isabel with no head marking, lighter purple/blue colored F593C (no washer) No spacers Isabel Spiral Lock Nut custom simulation test piece Aluminum fixture top - bolt through non threaded hole
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Bolt 1			
Torque	Torque	Tension	
T (in-lbs)	T (ft-lbs)	Fp (lbs)	K
60	5	500	0.320
120	10	1100	0.291
180	15	1500	0.320
240	20	2000	0.320
300	25	2500	0.320
360	30	3100	0.310
420	35	3800	0.295
480	40	--	--
540	45	--	--
Bolt 1 Average K			0.311

Tested By:	Ryan Siddon, Jeremy Downs	Signature or initials:	<i>RWS</i> - <i>JND</i>	Comp. Date	5/4/18
Reviewed By:	JND	Signature or initials:			
Test Equipment Used:	1, 2, 3, 4, 5	Sample No:	Various. See above and sample page.		
Amb (°C):	24.6	RH%	49		

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. A shearing load was applied to the end of the bar. 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 ≥ 0.020 in in movement (marked in red below).

Results of Tests

Testing Configuration:	4" blue coated F593C with two part locking washer 3/4" + 1/2" + 1/16" rough textured spacer rings 4" rough textured base extension Aluminum fixture top
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Pre-Test Torque Values						
Bolts	1	2	3	4	5 (Thr)	6 (Thr)
Bolt torques (in-lbs)	330	330	330	330	330	330

T=D*K*Fp	
K	0.234
D	0.375
Fp	3778
T	331.5

Gauge Start (in)	0.0028					
Can to spacer (in)	0.241	Start				
Can to spacer (in)	0.254	End	Delta (in)	0.013		
Spacer to fixture (in)	0.081	Start				
Spacer to fixture (in)	0.129	End	Delta (in)	0.048		

Direction	Aft						
Force (lbs)	500	1000	1500	2000	2500	3000	3500
Measured slippage per loading (in)							
Gauge Start (in)	0.0028	0.0028	0.0028	0.0028	0.0027	0.0027	0.0026
Gauge End (in)	0.0028	0.0028	0.0028	0.0027	0.0027	0.0026	0.0026
Slippage (in)	0.0000	0.0000	0.0000	0.0001	0.0000	0.0001	0.0000
Total Slippage (in)	0.0000	0.0000	0.0000	0.0001	0.0001	0.0002	0.0002

Force (lbs)	4000	4500	5000	5500	6000	6500	7000
Measured slippage per loading (in)							
Gauge Start (in)	0.0026	0.0025	0.0023	0.0022	0.0021	0.0019	0.0017
Gauge End (in)	0.0025	0.0023	0.0022	0.0021	0.0019	0.0017	0.0014
Slippage (in)	0.0001	0.0002	0.0001	0.0001	0.0002	0.0002	0.0003
Total Slippage (in)	0.0003	0.0005	0.0006	0.0007	0.0009	0.0011	0.0014

Force (lbs)	7500	8000	8500	9000	9500	10000	10500
Measured slippage per loading (in)							
Gauge Start (in)	0.0014	0.0012	0.0010	0.0008	0.0005	0.0000	-0.0003
Gauge End (in)	0.0012	0.0010	0.0008	0.0005	0.0000	-0.0003	-0.0007
Slippage (in)	0.0002	0.0002	0.0002	0.0003	0.0005	0.0003	0.0004
Total Slippage (in)	0.0016	0.0018	0.0020	0.0023	0.0028	0.0031	0.0035

Force (lbs)	11000	11500	12000	12500	13000	13500	14000
Measured slippage per loading (in)							
Gauge Start (in)	-0.0007	-0.0013	-0.0017	-0.0025	-0.0031	-0.0039	-0.0049
Gauge End (in)	-0.0013	-0.0017	-0.0025	-0.0031	-0.0039	-0.0049	-0.0059
Slippage (in)	0.0006	0.0004	0.0008	0.0006	0.0008	0.0010	0.0010
Total Slippage (in)	0.0041	0.0045	0.0053	0.0059	0.0067	0.0077	0.0087

Force (lbs)	14500	15000	15500	16000	16500	17000	17500
Measured slippage per loading (in)							
Gauge Start (in)	-0.0059	-----	-----	-----	-----	-----	-----
Gauge End (in)	-0.0322	-----	-----	-----	-----	-----	-----
Slippage (in)	0.0263	-----	-----	-----	-----	-----	-----
Total Slippage (in)	0.0350	-----	-----	-----	-----	-----	-----


F=μFn

F	Fn	μ
14500	22668	0.64

Post-Test Torque Values						
Bolts	1	2	3	4	5 (Thr)	6 (Thr)
Bolt torques (in-lbs)	290	280	290	310	290	290

Observations:

Photo below shows the contact and abrasion between the rough textured spacer and the bottom of the aluminum fixture top. There is no actual damage to the bottom of the fixture or the top spacer.



Complies: N/A

Tested By:	Ryan Siddon, Jeremy Downs	Signature or initials:	RWS	Comp. Date	5/3/18
Reviewed By:	JND	Signature or initials:	JND		
Test Equipment Used:	1, 2, 3, 4, 5, 6, 7	Sample No:	Various. See above and sample page.		
Amb (°C):	26	RH%	57		

Testing Configuration:	3" blue coated SUPER bolt w/ Grade 8 Nut - no washer 3/4" + 1/2" Class 1A Galvanized Spacer Rings 4" Class 1A Galvanized textured base extension Aluminum fixture top
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Pre-Test Torque Values						
Bolts	1	2	3	4	5 (Thr)	6 (Thr)
Bolt torques (in-lbs)	all bolts approximately 1000					

T=D*K*Fp	
K	0.298
D	0.375
Fp	8719
T	974.3

Gauge Start (in)	0.0001					
Can to spacer (in)	0.22	Start				
Can to spacer (in)	0.23	End	Delta (in)	0.01		
Spacer to fixture (in)	0.069	Start				
Spacer to fixture (in)	0.083	End	Delta (in)	0.014		

Direction	Aft						
Force (lbs)	500	1000	1500	2000	2500	3000	3500
Measured slippage per loading (in)							
Gauge Start (in)	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Gauge End (in)	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Slippage (in)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total Slippage (in)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Force (lbs)	4000	4500	5000	5500	6000	6500	7000
Measured slippage per loading (in)							
Gauge Start (in)	0.0001	0.0001	0.0001	0.0001	0.0000	0.0007	-0.0021
Gauge End (in)	0.0001	0.0001	0.0001	0.0000	0.0007	-0.0021	-0.0050
Slippage (in)	0.0000	0.0000	0.0000	0.0001	0.0007	0.0028	0.0029
Total Slippage (in)	0.0000	0.0000	0.0000	0.0001	0.0008	0.0036	0.0065

Force (lbs)	7500	8000	8500	9000	9500	10000	10500
Measured slippage per loading (in)							
Gauge Start (in)	-0.0050	-0.0090	-0.0140	----	----	----	----
Gauge End (in)	-0.0090	-0.0140	-0.0200	----	----	----	----
Slippage (in)	0.0040	0.0050	0.0060	----	----	----	----
Total Slippage (in)	0.0105	0.0155	0.0215	----	----	----	----

F=μFn		
F	Fn	μ
8500	52314	0.16

Post-Test Torque Values						
Bolts	1	2	3	4	5 (Thr)	6 (Thr)
Bolt torques (in-lbs)	920	890	890	890	850	890

Observations:	No Damage
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Testing Configuration:	William System
	4" Isabel with no head marking, lighter purple/blue colored F593C (no washer) w/ Clips 3.75" blue coated flat head bevelled F593C (no washer) Isabel Spiral Lock Nuts 4" Class 1A Galvanized Base Extension 3/4" Class 1A galvanized spacer ring w/ countersunk through holes 1/2" + 1/4" Class 1A galvanized spacer rings Aluminum fixture top

Pre-Test Torque Values						
Bolts	1	2	3	4	5 (Thr)	6 (Thr)
Isabel Bolt torques (in-lbs)	460	460	460	460	460	460
Countersunk Bolt torques (in-lbs)	390	390	390	390	390	390

T=D*K*Fp	
K	0.325
D	0.375
Fp	3778
T	460.4
ISABEL	

Gauge Start (in)	0.003			
Can to 1/4" spacer (in)	0.2585	Start		
Can to 1/4" spacer (in)	0.248	End	Delta (in)	0.0105
1/4" to 3/4" spacer (in)	0.0655	Start		
1/4" to 3/4" spacer (in)	0.062	End	Delta (in)	0.0035
3/4" Spacer to fixture (in)	0.0535	Start		
3/4" Spacer to fixture (in)	0.09	End	Delta (in)	0.0365

T=D*K*Fp	
K	0.412
D	0.375
Fp	2500
T	386.3
Countersunk	

Direction	Aft						
Force (lbs)	500	1000	1500	2000	2500	3000	3500
Measured slippage per loading (in)							
Gauge Start (in)	0.0030	0.0030	0.0029	0.0026	0.0021	-0.0072	-0.0152
Gauge End (in)	0.0030	0.0029	0.0026	0.0021	-0.0072	-0.0152	-0.0250
Slippage (in)	0.0000	0.0001	0.0003	0.0005	0.0093	0.0080	0.0098
Total Slippage (in)	0.0000	0.0001	0.0004	0.0009	0.0102	0.0182	0.0280

Force (lbs)	4000	4500	5000	5500	6000	6500	7000
Measured slippage per loading (in)							
Gauge Start (in)	-0.0250	-0.0333	-0.0383	----	----	----	----
Gauge End (in)	-0.0333	-0.0383	-0.0455	----	----	----	----
Slippage (in)	0.0083	0.0050	0.0072	----	----	----	----
Total Slippage (in)	0.0363	0.0413	0.0485	----	----	----	----

F=μFn		
F	Fn	μ
3500	22668	0.15

Post-Test Torque Values						
Bolts	1	2	3	4	5 (Thr)	6 (Thr)
Isabel Bolt torques (in-lbs)	420	430	410	410	400	400

Observations: No Damage -- most of the slippage occurred between the top spacer ring and the aluminum fixture top. The calculated normal force (Fn) is only from the 6 fixture bolts (Isabel bolts).

Complies: N/A

Tested By:	Ryan Siddon, Jeremy Downs	Signature or initials:	RWS	Comp. Date	5/4/18
Reviewed By:	JND	Signature or initials:	JND		
Test Equipment Used:	1, 2, 3, 4, 5, 6, 7	Sample No:	Various. See above and sample page.		
Amb (°C):	26.8	RH%	53		

Testing Configuration:	William System
	4" Isabel with no head marking, lighter purple/blue colored F593C (no washer) w/ Clips 3.75" blue coated flat head bevelled F593C (no washer) Isabel Spiral Lock Nuts 4" rough textured Base Extension 3/4" rough textured spacer ring w/ countersunk through holes 1/2" + 1/4" rough textured spacer rings Aluminum fixture top

Pre-Test Torque Values						
Bolts	1	2	3	4	5 (Thr)	6 (Thr)
Isabel Bolt torques (in-lbs)	460	460	460	460	460	460
Countersunk Bolt torques (in-lbs)	390	390	*	390	390	390

T=D*K*Fp	
K	0.325
D	0.375
Fp	3778
T	460.4
ISABEL	

Gauge Start (in)	0.0008					
Can to spacer (in)	0.252	Start				
Can to spacer (in)	0.251	End	Delta (in)	0.001		
Spacer to fixture (in)	0.08	Start				
Spacer to fixture (in)	0.1105	End	Delta (in)	0.0305		

*Top center bolt couldn't be torqued fully to 390, but nut was snug to flange -- Allen key hole became "stripped" from torquing

Direction	Aft						
Force (lbs)	500	1000	1500	2000	2500	3000	3500
Measured slippage per loading (in)							
Gauge Start (in)	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
Gauge End (in)	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
Slippage (in)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total Slippage (in)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

T=D*K*Fp	
K	0.412
D	0.375
Fp	2500
T	386.3
Countersunk	

Force (lbs)	4000	4500	5000	5500	6000	6500	7000
Measured slippage per loading (in)							
Gauge Start (in)	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
Gauge End (in)	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
Slippage (in)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total Slippage (in)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Force (lbs)	7500	8000	8500	9000	9500	10000	10500
Measured slippage per loading (in)							
Gauge Start (in)	0.0008	0.0007	-0.0031	-0.0040	-0.0065	-0.0080	-0.0100
Gauge End (in)	0.0007	-0.0031	-0.0040	-0.0065	-0.0080	-0.0100	-0.0116
Slippage (in)	0.0001	0.0038	0.0009	0.0025	0.0015	0.0020	0.0016
Total Slippage (in)	0.0001	0.0039	0.0048	0.0073	0.0088	0.0108	0.0124

Force (lbs)	11000	11500	12000	12500	13000	13500	14000
Measured slippage per loading (in)							
Gauge Start (in)	-0.0116	-0.0135	-0.0165	-0.0210	-0.0300	-----	-----
Gauge End (in)	-0.0135	-0.0165	-0.0210	-0.0300	-0.0318	-----	-----
Slippage (in)	0.0019	0.0030	0.0045	0.0090	0.0018	-----	-----
Total Slippage (in)	0.0143	0.0173	0.0218	0.0308	0.0326	-----	-----

F=μFn

F	Fn	μ
12000	22668	0.53

Post-Test Torque Values							
Bolts	1	2	3	4	5 (Thr)	6 (Thr)	
Isabel Bolt torques (in-lbs)	430	450	440	450	460	460	

Observations: No Damage -- most of the slippage occurred between the top spacer ring and the aluminum fixture top. The calculated normal force (Fn) is only from the 6 fixture bolts (Isabel bolts).

Complies: N/A

Tested By:	Ryan Siddon, Jeremy Downs	Signature or initials:	RWS	Comp. Date	5/7/18
Reviewed By:	JND	Signature or initials:	JND		
Test Equipment Used:	1, 2, 3, 4, 5, 6, 7		Sample No:	Various. See above and sample page.	
Amb (°C):	26.2	RH%	31		

Equipment list				
#	Intertek ID No.	Description	Manufacturer	Calibration Due
1	M274	Hygrothermometer	Extech	03-Nov-2018
2	M280	Bolt Tension Calibrator	Skidmore Wilhelm	22-Nov-2018
3	M278	Dial Torque Wrench	CDI Torque Products Inc.	04-Jan-2019
4	M279	Digital Torque Wrench	Imada	17-Nov-2018
5	M283	Digital Calipers	Mitutoyo	21-Apr-2019
6	S108	Press	Tinius Olsen	01-May-2019
7	N1266	Digital Indicator	B.C. Ames Co.	18-Jan-2019

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