atis PROTECTION ENGINEERS GROUP

HUNTSVILLE, AL - MARCH 13-15, 2018

Torque and Electrical Connectors

Presented by:
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Hubbell – BURNDY LLC

Last Code cycle was to snug up the connection, then go another 1/2 turn. Now we must use a "calibrated" torque wrench whatever that means, And the manufactures label gives a number but no tolerance value. Who can hit it exactly on the number? You will always be over or under. How will the inspector check it. If he puts his wrench on it he will violate accepted torque rules. Some panel messed up this time.. SemiRet 2 2017

Today's Discussion

- Why do we need to revisit wire terminations and torque today?
- What is torque at the engineering level and how does that translate to electrical connections?
- What data do we have in the industry and what do the connector standards say about it?
- Retighten, re-torque, re-termination? When is ok, Which is it and What is right?
- What's coming?

Why discuss now…2017 NEC Change

- NEW - Article 110.14D

(D) Installation. Where a tightening torque is indicated as a numeric value on equipment or in installation instructions provided by the manufacturer, a calibrated torque tool shall be used to achieve the indicated torque value, unless the equipment manufacturer has provided installation instructions for an alternative method of achieving the required torque.

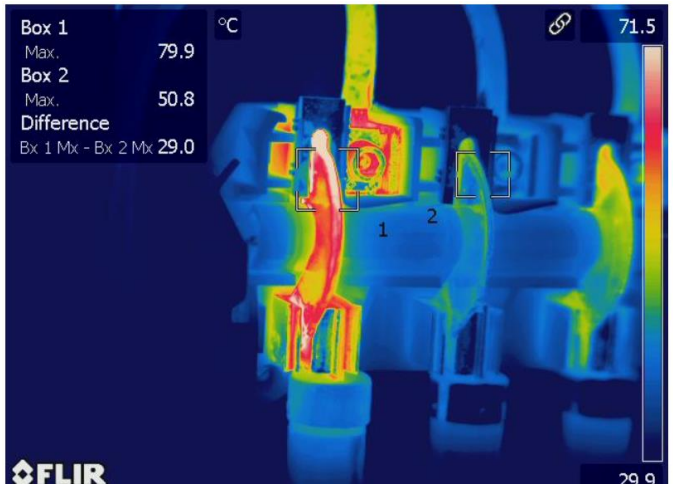
- 19 States have adopted the 2017 Code as of Feb, 2018.

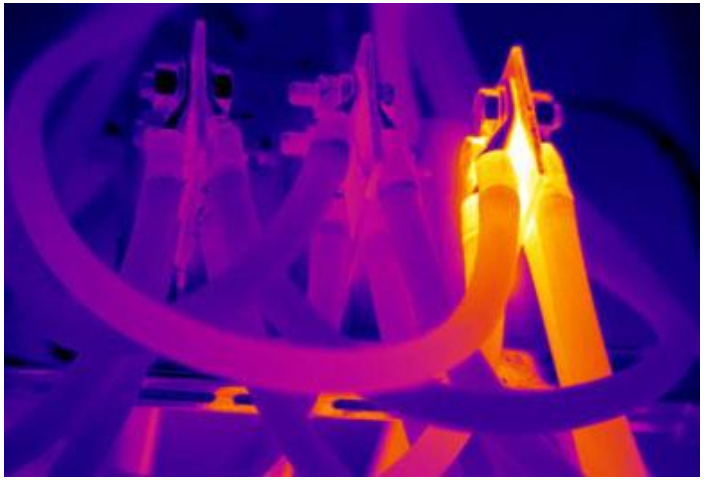
"*I'm going to leave all my connections hand tight and let the inspector torque them. That's the only real way it can be shown*." Rephase 277 Feb, 2017

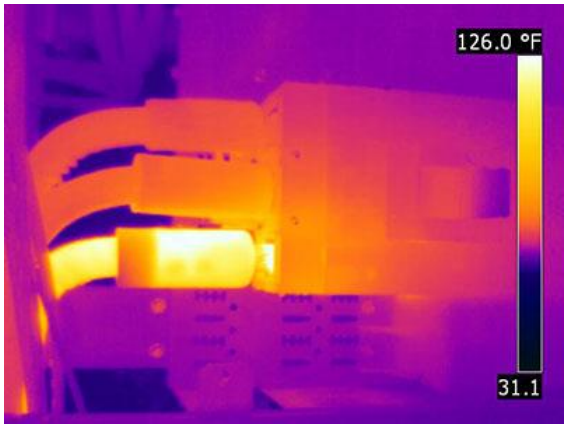
"*I see this code as practically unenforceable even if the inspector was with you at every termination (not likely), and your torque tools are properly calibrated.*" Varmit , Feb, 2017

Electrician Talk - 2017

We've all seen the IR photos of the hot connector…..

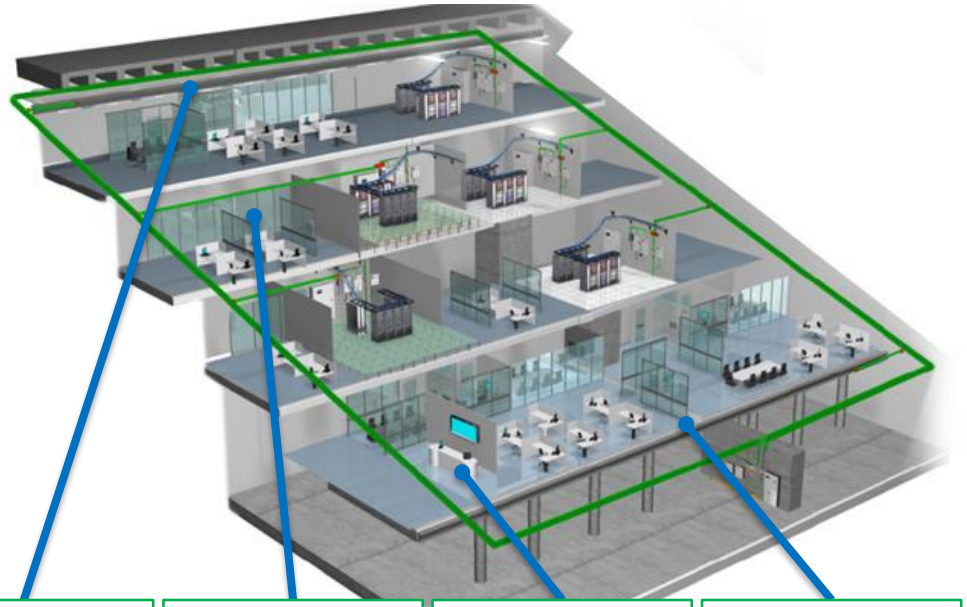






Systems Overview – Grounding "flow"

Static Points

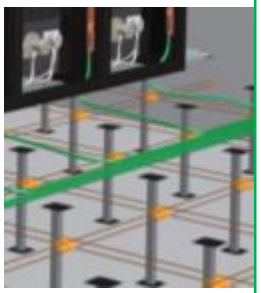


Generation Points

Bonding Components

RGB

Bonding Network MBN TEBC



Busbars (TGB)

Backbone (TBB)

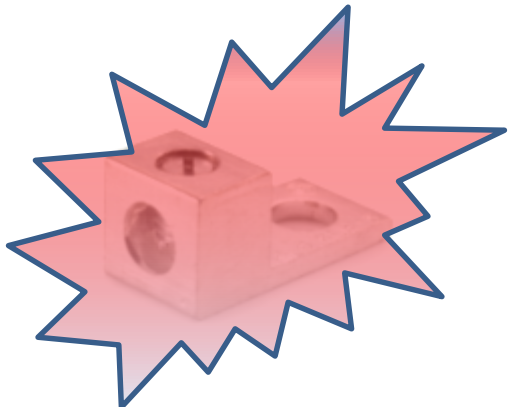
Exit (TMGB, GND)

Components

- Compression:
  - C-Tap
  - H-Tap
  - Bus bar & I-Beam Tap
  - Terminals and mounting hardware
- Mechanical: (Use Torque Device)
  - Pipe & Raised Floor Clamps
  - Split Bolt
  - Lug



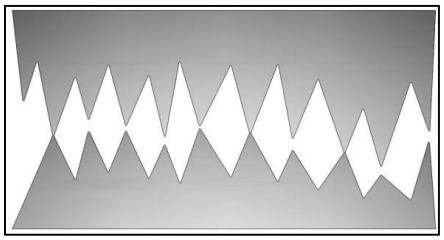




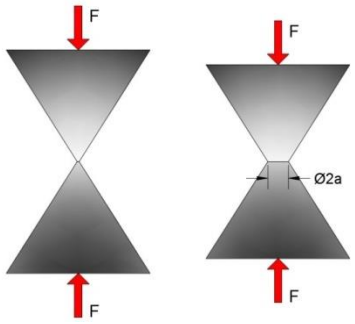
VIOLATION	Acceptable
-Mechanical Connector ON bus bar - Bus holes not Drilled to match lug - Braid field terminated? 	+Comp lug with matching hole pattern +Busbar Taps +Exothermic Welding 

*Does anybody believe the connections on the left had recommended torque applied?

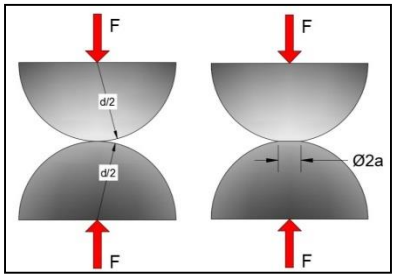
Some connector theory is needed first



- All pressure connections look something like this at the microscopic level.

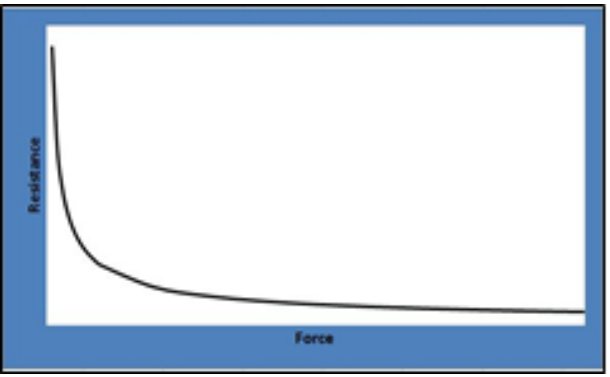


- As pressure is applied the points of contact are deformed to create "A" spots.

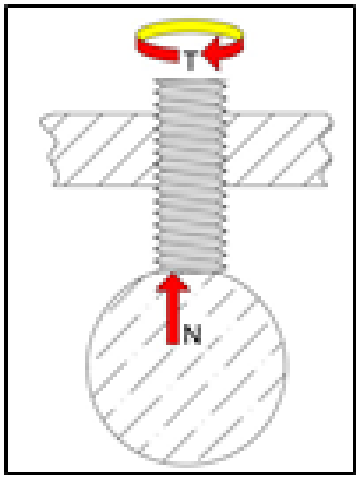


- For analysis, this can be reduced to two spheres and can be mathematically modeled using Young's Modulus and Poison's theory to functions of material properties of resistivity.

Connector theory continued..

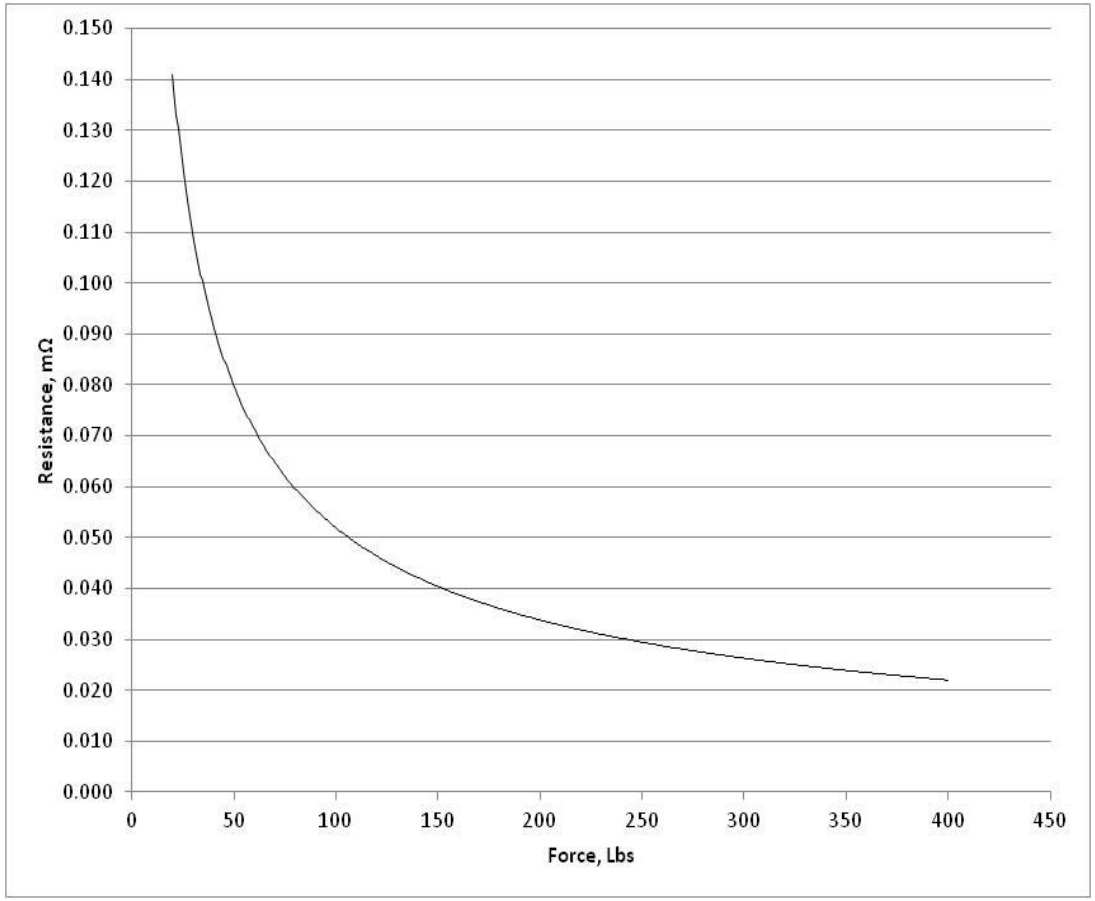


When applied force is increased the contact resistance reduces. This is both intuitive and backed up by experience and data. What isn't intuitive is the phenomenon of diminished returns.

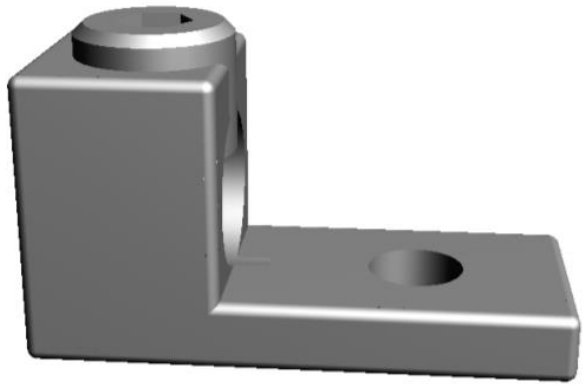


- Friction, our enemy or friend. Even changing the material of the conductor can cause the force/torque relationship to change.
- Aluminum and copper have different frictional interactions with various metals.
- A torque that works well on one conductor may not necessarily work on the other. Over torque can shear strands if the fastener moves during torque. All variable.
- All design challenges for the connector manufacturer. Torque is the one installer requirement most critical to performance.

#2 Class B copper, in an aluminum body set screw connector, 40 micro ohms of resistance with 150 inch pounds of torque.



Connector theory actual data……



Please don't change the recommended Torque ….

Originally Posted by chrisfnl -
*If someone actually follows the directions in the pm, and re-tightens, seldom do they have a **torque** wrench with them, and even less do they have a **torque** screw driver... So they use a regular wrench or screw driver and just give it a little extra twist...*

"I agree, I'll admit I have broken too many things trying to get it just a little tighter. For this kind of thing I think the usual method is to set the **torque** wrench just below the installation **torque** spec, and crank away. If it clicks, stop, it's ok; if the fastener moves, stop and set it to the install **torque** spec, and tighten it down until it clicks." SPLAZ, May

Near as I can tell, if we always use the manufacturers torque specs, I think we're going to see a lot more stuff burn up. MICROMIND Aug 2017

NEC Annex I

- **Informative Annex I Recommended Tightening Torque Tables from UL Standard 486A-B**
- *This informative annex is not a part of the requirements of this NFPA*
- *document, but is included for informational purposes only.*
- In the absence of connector or equipment manufacturer's recommended torque values, Table I.1, Table I.2, and Table I.3 may be used to correctly tighten screw-type connections for power and lighting circuits*. Control and signal circuits may require different torque values, and the manufacturer should be contacted for guidance.
- *For proper termination of conductors, it is very important that field connections be properly tightened. In the absence of manufacturer's instructions on the equipment, the torque values given in these tables are recommended.
- Because it is normal for some relaxation to occur in service, checking torque values sometime after installation is **not** a reliable means of determining the values of torque applied at installation.

Notice anything familiar……

Table I.1 Tightening Torque for Screws

Test Conductor Installed in Connector		Tightening Torque, N-m (lbf-in.)							
		Slotted head No. 10 and larger*							
		Slot width 1.2 mm (0.047 in.) or less and slot length 6.4 mm (¼ in.) or less		Slot width over 1.2 mm (0.047 in.) or slot length over 6.4 mm (¼ in.)		Split-bolt connectors		Other connectors	
AWG or kcmil	mm²								
30–10	0.05–5.3	2.3	(20)	4.0	(35)	9.0	(80)	8.5	(75)
8	8.4	2.8	(25)	4.5	(40)	9.0	(80)	8.5	(75)
6–4	13.2–21.2	4.0	(35)	5.1	(45)	18.5	(165)	12.4	(110)
3	26.7	4.0	(35)	5.6	(50)	31.1	(275)	16.9	(150)
2	33.6	4.5	(40)	5.6	(50)	31.1	(275)	16.9	(150)
1	42.4	—		5.6	(50)	31.1	(275)	16.9	(150)
1/0–2/0	53.5–67.4	—		5.6	(50)	43.5	(385)	20.3	(180)
3/0–4/0	85.0–107.2	—		5.6	(50)	56.5	(500)	28.2	(250)
250–350	127–177	—		5.6	(50)	73.4	(650)	36.7	(325)
400	203	—		5.6	(50)	93.2	(825)	36.7	(325)
500	253	—		5.6	(50)	93.2	(825)	42.4	(375)
600–750	304–380	—		5.6	(50)	113.0	(1000)	42.4	(375)
800–1000	405–508	—		5.6	(50)	124.3	(1100)	56.5	(500)
1250–2000	635–1010	—		—		124.3	(1100)	67.8	(600)

*For values of slot width or length not corresponding to those specified, select the largest torque value associated with the conductor size. Slot width is the nominal design value. Slot length shall be measured at the bottom of the slot.

From GR1275 Telcordia Standard on the subject…

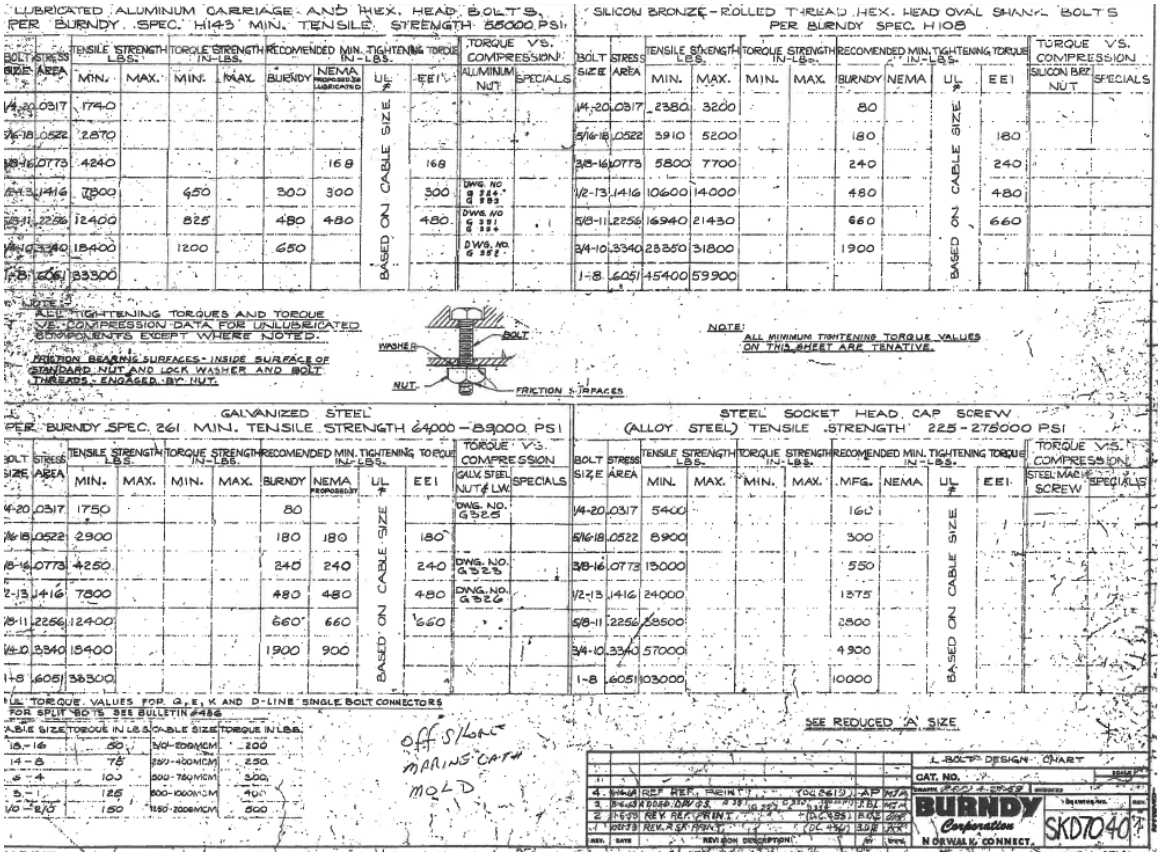
9.7 General Technical References and Torque Requirements

R9-26	**[1342]** The Installation Supplier shall torque fasteners (e.g., nuts and bolts) that have torque requirements specified by the manufacturer, the job documentation, or this GR. See Table 9-1.
CR9-27	**[1343]** The torqued item shall be marked by the Installation Supplier, e.g., across the nut, with an indelible ink mark to confirm that the torque adjustment has been made.

- Bonding and Grounding - Integrated Ground Plane 18–1
- **R18-13 [1788]** All grounding material (e.g., conductors, cable, connectors, bus bars) shall be made of copper or plated copper.

  NOTE: Fasteners (i.e., bolts, nuts, washers) may be other than copper (e.g., silicon bronze or steel). For torque information, see Table 9-1, “Bolt Grade and Torque Specification Table.”

Where did all this come from?


LUBRICATED ALUMINUM CARRIAGE AND HEX. HEAD BOLTS, PER BURNDY SPEC. H143 MIN. TENSILE STRENGTH 55000 PSI.

BOLT SIZE	STRESS AREA	TENSILE STRENGTH LBS. MIN.	TENSILE STRENGTH LBS. MAX.	TORQUE STRENGTH IN-LBS. MIN.	TORQUE STRENGTH IN-LBS. MAX.	RECOMENDED MIN. TIGHTENING TORQUE IN-LBS. BURNDY	RECOMENDED MIN. TIGHTENING TORQUE IN-LBS. NEMA PROPOSED (LUBRICATED)	UL	EEI	TORQUE VS. COMPRESSION ALUMINUM NUT	TORQUE VS. COMPRESSION SPECIALS
1/4-20	.0317	1740									
5/16-18	.0522	2870									
3/8-16	.0775	4240				168			168		
1/2-13	.1416	7800		450		300	300		300	DWG. NO. G 264 G 293	
5/8-11	.2256	12400		825		480	480		480	DWG. NO. G 281 G 294	
3/4-10	.3340	18400		1200		650				DWG. NO. G 282	
1-8	.6051	33300									

BASED ON CABLE SIZE

NOTE: ALL TIGHTENING TORQUES AND TORQUE VS. COMPRESSION DATA FOR UNLUBRICATED COMPONENTS EXCEPT WHERE NOTED.

FRICTION BEARING SURFACES - INSIDE SURFACE OF STANDARD NUT AND LOCK WASHER AND BOLT THREADS ENGAGED BY NUT.

SILICON BRONZE - ROLLED THREAD HEX. HEAD OVAL SHANK BOLTS PER BURNDY SPEC. H108

BOLT SIZE	STRESS AREA	TENSILE STRENGTH LBS. MIN.	TENSILE STRENGTH LBS. MAX.	TORQUE STRENGTH IN-LBS. MIN.	TORQUE STRENGTH IN-LBS. MAX.	RECOMENDED MIN. TIGHTENING TORQUE IN-LBS. BURNDY	RECOMENDED MIN. TIGHTENING TORQUE IN-LBS. NEMA	UL	EEI	TORQUE VS. COMPRESSION SILICON BRZ. NUT	TORQUE VS. COMPRESSION SPECIALS
1/4-20	.0317	2380	3200			80					
5/16-18	.0522	3910	5200			180			180		
3/8-16	.0775	5800	7700			240			240		
1/2-13	.1416	10600	14000			480			480		
5/8-11	.2256	16940	21430			660			660		
3/4-10	.3340	23850	31800			1900					
1-8	.6051	45400	59900								

BASED ON CABLE SIZE

NOTE: ALL MINIMUM TIGHTENING TORQUE VALUES ON THIS SHEET ARE TENATIVE.

GALVANIZED STEEL PER BURNDY SPEC. 261 MIN. TENSILE STRENGTH 64000 - 89000 PSI

BOLT SIZE	STRESS AREA	TENSILE STRENGTH LBS. MIN.	TENSILE STRENGTH LBS. MAX.	TORQUE STRENGTH IN-LBS. MIN.	TORQUE STRENGTH IN-LBS. MAX.	RECOMENDED MIN. TIGHTENING TORQUE IN-LBS. BURNDY	RECOMENDED MIN. TIGHTENING TORQUE IN-LBS. NEMA PROPOSED	UL	EEI	TORQUE VS. COMPRESSION GALV. STEEL NUT & LW.	TORQUE VS. COMPRESSION SPECIALS
1/4-20	.0317	1750				80				DWG. NO. G525	
5/16-18	.0522	2900				180	180		180		
3/8-16	.0773	4250				240	240		240	DWG. NO. G525	
1/2-13	.1416	7800				480	480		480	DWG. NO. G525	
5/8-11	.2256	12400				660	660		660		
3/4-10	.3340	15400				1900	900				
1-8	.6051	38300									

BASED ON CABLE SIZE

UL TORQUE VALUES FOR G, E, K AND D-LINE SINGLE BOLT CONNECTORS FOR SPLIT BOLTS SEE BULLETIN #486

CABLE SIZE	TORQUE IN LBS.	CABLE SIZE	TORQUE IN LBS.
16-16	50	1/0-250MCM	200
14-8	75	251-400MCM	250
6-4	100	500-750MCM	300
3-1	125	800-1000MCM	400
1/0-2/0	150	1150-2000MCM	600

STEEL SOCKET HEAD CAP SCREW (ALLOY STEEL) TENSILE STRENGTH 225 - 275000 PSI

BOLT SIZE	STRESS AREA	TENSILE STRENGTH LBS. MIN.	TENSILE STRENGTH LBS. MAX.	TORQUE STRENGTH IN-LBS. MIN.	TORQUE STRENGTH IN-LBS. MAX.	RECOMENDED MIN. TIGHTENING TORQUE IN-LBS. MFG.	RECOMENDED MIN. TIGHTENING TORQUE IN-LBS. NEMA	UL	EEI	TORQUE VS. COMPRESSION STEEL MACH. SCREW	TORQUE VS. COMPRESSION SPECIALS
1/4-20	.0317	5400				160					
5/16-18	.0522	8900				300					
3/8-16	.0773	13000				550					
1/2-13	.1416	24000				1375					
5/8-11	.2256	38500				2800					
3/4-10	.3340	57000				4900					
1-8	.6051	103000				10000					

BASED ON CABLE SIZE

SEE REDUCED 'A' SIZE

off SIGHT MARING CATH MOLD

1 BOLT DESIGN CHART

CAT. NO.

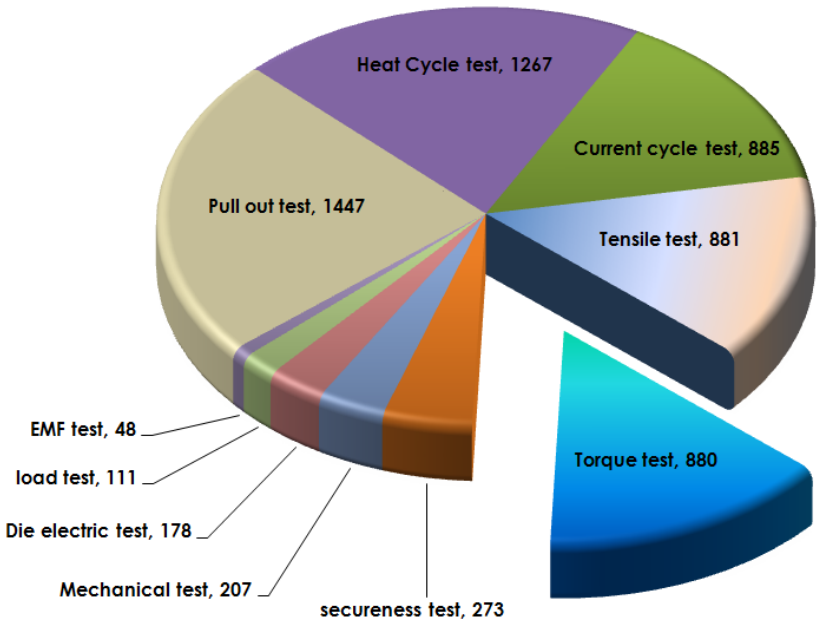
BURNDY Corporation NORWALK, CONNECT.

SKD7040

The oldest document we could find in our PDM system with UL, NEMA, EEI and internal comparisons of recommended torque for fasteners …….1959. Same values as today across the industry standards and being reconfirmed with current models and tests.

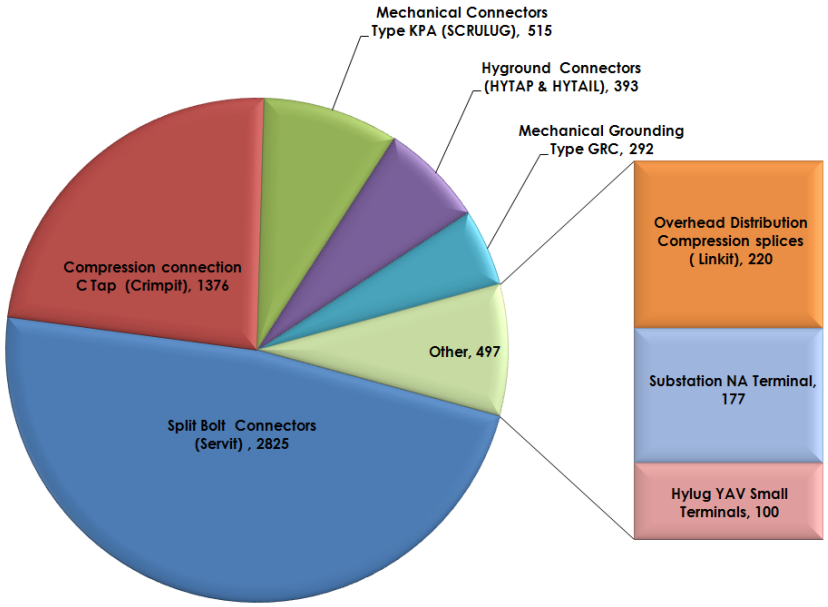
So how much empirical data is there….

Type of connector tests since 1924



- Over 800 tests dedicated to torque and performance.
- All mechanical connectors had a recorded torque value making it in the 1000's.
- Multiply times all the connector companies in US…….

Within that data….



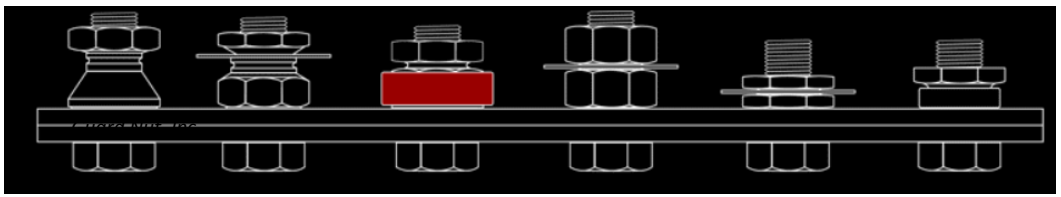
- 10,482 specific tests of mechanical fastener connectors through 1/2016 with various torque values.
- Only at one company among the many N. American standards based manufacturers.

After the initial torque, what is required…

- If you follow GR1275 recommendations, UL486 A&B, and all NEMA members recommendations, make a permanent mark across the fastener (bolt/nut, set screw/body) after initial proper torque and if that mark shows no movement, do not touch it.
- But I have high vibration at my equipment? No.
- But I don't know if the installer made the initial torque correctly? No.
  - If over torqued, checking it will not show you that value.
  - If under-torqued, same issue. Will new torque be just friction reading?
  - Relaxation may indicate under-torque but it may not be. Tests indicate 85% of relaxation of an Aluminum termination will have occurred within 5 mins of initial installation torque.
    - How many times are you going to re-torque and when? If under-torqued severely and the connection has been overheated, tightening it to the recommended torque has been shown to restore the connection less than 15% of the time. Re-termination is the only sound choice.

What is coming to make this easier?

- There are fasteners on the market today and certainly new ones to come that will claim to provide accurate (+/-5%) torque values.
- Do these torque head fasteners result in correct conductor pressure? Remember all the variables we discussed…..not as a stand alone element.
- Affordable torque tools and adapters are on the market today that can provide +/-5%. Every bolted connection in telecom facilities are critical. Do it right at installation.



References and further reading

1) McPartland,J.F., "All Electricals Must Be Torqued!," Electrical construction and Maintenance,1983.

2) Di Trioia,G., K. Woo, and G.Zahlman, Connector Theory and Application by Burndy LLC 2010

3) Matthysee, I. F., "Basic Connection Principles," Second edition, BURNDY Corporation, 1965.

4) Ron Newport, "Infrared Electrical Inspection Myths",1998

5) Richard L.Nailen,P.E.,EA engineering editors ,Electrical Apparatus, on 2006 Barks Publications.

6) Richard Skidmore, Tightening torque for Bolts,1958.

7) Jefferey A.Fecteau "Electrical Connections ,a supplement of The Code Authority (UL)" July 2013

8) Matthysee, I. F., "Is It Necessary to retighten clam connectors," Electric World ,May,1951.

9) UL 486A-486B., "Standard For Safety, Wire Connectors" ,January 11, 2013.

10) NFPA® "National Electric Code®",2014.

11) Telcordia, GR1275, Ericsson, Telcordia Technologies Inc., December 2010.

12) Balathandayutham Thiyagarajan , Lee Herron ,Sivasakthipriyan Kasi, "Theory of the Effect of Torque and Re-Torque Practices on Electrical Connectors with Clamping Fasteners", IEEE PICON 4 2016.