Conductor Ampacity
4-pair Communications Cables

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Purpose

•Review NEC 2nd draft Code Making Panel (CMP) 3 and CMP 16 revisions as of week of November 2nd in consideration of Public Comment No. 1441-NFPA 70-2015 [Section No. 840.160]

- CMP 16 - Chapter 8 Article 840.160 for Communications Circuits
- CMP 3 - Chapter 7 Article 725.144 for Power Circuits

•Comparison of Table [725.144], 802.3bt current per pair/conductor specification, and TSB-184-A temperature rise versus bundle size.

- How does the Table apply to the currents proposed in IEEE 802.3bt 4PPoE?

- Consideration for 802.3 Link Segment performance > 60 deg C.

- Review elevated temperatures on channel performance

Chapter 8 - Article 840.160

- 2nd draft revision to include;
  - 840.160 Communications Circuits - Communications cables, in addition to carrying the communications circuit shall also be permitted to carry circuits for powering communications equipment. Where the power supplied over a communications cable to communications equipment is more than 60 watts, communications cable and the powering circuits shall comply with 725.144 where communications cables are used as substitute to Class 2 and 3 cables.

Chapter 7 - Article 725.144

- 2nd draft revision to include;

725.144 Transmission of Power and Data.
The requirements of 725.144(A) and (B) shall apply to Class 2 and Class 3 circuits that transmit power and data to a powered device. The requirements of Parts I and Ill of Article 725 and 300.11 shall apply to Class 2 and Class 3 circuits that transmit power and data. The conductors that carry power for the data circuits shall be copper. The current in the power circuit shall not exceed the current limitation of the connectors.

Informational Note No. 1: One example of the use of cables that transmit power and data is the connection of closed circuit TV Cameras (CCTV).

Informational Note No. 2: The 8P8C connector is in widespread use with powered communications systems. These connectors are typically rated at 1.3 amperes maximum.

(A) Use of Class 2 or Class 3 Cables to Transmit Power and Data. Where Types CL3P, CL2P, CL3R, CL2R, CL3, or CL2 transmit power and data, the following shall apply, as applicable.

Chapter 7 - Article 725.144

- 2nd draft revision to include;

725.144 Transmission of Power and Data. (cont)

(1) The ampacity ratings in Table 725.144 shall apply at an ambient temperature of 30°C (86°F).
(2) For ambient temperatures above 30°C (86°F), the correction factors of 310.15(8)(2) shall apply.

Informational Note: One example of the use of Class 2 cables is a network of closed circuit TV cameras using 24 AWG.60°C rated, Type CL2R, Category 5e LAN {local area network) cables.

Table 725.144, Ampacities of Each Conductor (in Amperes) in a 4-Pair Class 2 or Class 3 Data Cables, Based on Copper Conductors at Ambient Temperature of 30°C (86° F) with all Conductors in All Cables Carrying Current, 60°C (140°F), 75°C (167°F) and 90°C (194°F) Rated Cables

AWG	Number of 4-Pair Cables in a Bundle																				
	1			2-7			8-19			20-37			38-61			62-91			92-192		
	Temperature Rating			Temperature Rating			Temperature Rating			Temperature Rating			Temperature Rating			Temperature Rating			Temperature Rating		
	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C
26	1.0	1.0	1.0	1.0	1.0	1.0	0.7	0.8	1.0	0.5	0.6	0.7	0.4	0.5	0.6	0.4	0.5	0.6	NA	NA	NA
24	2.0	2.0	2.0	1.0	1.4	1.6	0.8	1.0	1.1	0.6	0.7	0.9	0.5	0.6	0.7	0.4	0.5	0.6	0.3	0.4	0.5
23	2.5	2.5	2.5	1.2	1.5	1.7	0.8	1.1	1.2	0.6	0.8	0.9	0.5	0.7	0.8	0.5	0.7	0.8	0.4	0.5	0.6
22	3.0	3.0	3.0	1.4	1.8	2.1	1.0	1.2	1.4	0.7	0.9	1.1	0.6	0.8	0.9	0.6	0.7	0.8	0.5	0.6	0.7

Note 1: For bundle sizes over 192 cables, or for conductor sizes smaller than 26 AWG, ampacities shall be permitted to be determined by qualified personnel under engineering supervision.

Note 2: Where only half of the conductors in each cable are carrying current, the values in the table shall be permitted to be increased by a factor of 1.4.

Informational Note: The conductor sizes in data cables in wide-spread use are typically 22 – 26 AWG.

Chapter 7 - Article 725.144

- 2nd draft revision to include;

725.144 Transmission of Power and Data. (cont)

(B) Use of Class 2-LP or Class 3-LP Cables to Transmit Power and Data. Types CL3P-LP, CL2P-LP. CL3R-LP, CL2R-LP, CL3-LP. Or CL2-LP shall be permitted to supply power to equipment at a current level up to the marked ampere limit located immediately following the suffix LP and shall be permitted to transmit data to the equipment. The Class 2-LP and Class 3-LP cables shall comply with the following: (B)(1) through (B)(3), as applicable.

Informational Note No. 1: The "(xxA}" following the suffix -LP indicates the ampacity of each conductor in a cable.

Informational Note No. 2: An example of a Limited Power (LP} cable is a cable marked Type CL2-LP(0.5A), 23 AWG. A Type CL2-LP(0.5), 23 AWG could be used in any location where a Type CL2 could be used, however. the LP cable would be suitable for carrying up to 0.5 A per conductor, regardless of the number of cables in a bundle. If used in a 7 cable bundle, the same cable could carry up to 1.2 amperes per conductor.

(1) Cables with the "-LP" suffix shall be permitted to be installed in bundles, raceways, cable trays, communications raceways, and cable routing assemblies.
(2) Cables with the suffix "-LP" and a marked ampere level shall follow the substitution hierarchy of Table 725.154(A) and Figure 725.154(A) for the cable type without the suffix "-LP: and without the marked ampere level.
(3) System design shall be permitted by qualified persons under engineering supervision.

Comparison

- Comparison requires common ambient temperature reference
  - TSB-184-A -Ambient temperature - 45 degree C
  - 802.3 references TSB-184 – Ambient temperature – 45 degree C

TIA TSB-184-A – 45 deg C Ambient

Table A.6 - Temperature rise v. cable bundle size (1000 mA per pair)

Number of Cables	Temperature Rise (°C)				
	26 AWG	C5e 1A	C6 1A	C6A 1A	Cat 8 1A
1	1.5	1.3	1.0	1.2	1.2
7	4.2	2.9	2.3	2.3	2.2
19	9.7	6.1	5.0	4.6	4.3
24	12.0	7.4	6.1	5.6	5.2
37	18.0	10.9	9.0	8.0	7.5
48	23.1	13.9	11.5	10.1	9.4
52	25.0	15.0	12.4	10.9	10.1
61	29.2	17.4	14.5	12.7	11.7
64	30.3	18.1	15.0	13.1	12.2
74	34.9	20.7	17.2	15.0	13.9
91	42.9	25.4	21.1	18.3	16.9
97	45.7	27.0	22.5	19.4	18.0
100	47.0	27.8	23.1	20.0	18.5
127	59.4	35.0	29.1	25.1	23.2
169	78.7	46.3	38.5	33.1	30.6

Comparison

- Table 725.144 - Ambient temperature - 30 deg c

Table 725.144, Ampacities of Each Conductor (in Amperes) in a 4-Pair Class 2 or Class 3 Data Cables, Based on Copper Conductors at Ambient Temperature of 30°C (86° F) with all Conductors in All Cables Carrying Current, 60°C (140°F), 75°C (167°F) and 90°C (194°F) Rated Cables

AWG	Number of 4-Pair Cables in a Bundle																				
	1			2-7			8-19			20-37			38-61			62-91			92-192		
	Temperature Rating			Temperature Rating			Temperature Rating			Temperature Rating			Temperature Rating			Temperature Rating			Temperature Rating		
	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C
26	1.0	1.0	1.0	1.0	1.0	1.0	0.7	0.8	1.0	0.5	0.6	0.7	0.4	0.5	0.6	0.4	0.5	0.6	NA	NA	NA
24	2.0	2.0	2.0	1.0	1.4	1.6	0.8	1.0	1.1	0.6	0.7	0.9	0.5	0.6	0.7	0.4	0.5	0.6	0.3	0.4	0.5
23	2.5	2.5	2.5	1.2	1.5	1.7	0.8	1.1	1.2	0.6	0.8	0.9	0.5	0.7	0.8	0.5	0.7	0.8	0.4	0.5	0.6
22	3.0	3.0	3.0	1.4	1.8	2.1	1.0	1.2	1.4	0.7	0.9	1.1	0.6	0.8	0.9	0.6	0.7	0.8	0.5	0.6	0.7

Note 1: For bundle sizes over 192 cables, or for conductor sizes smaller than 26 AWG, ampacities shall be permitted to be determined by qualified personnel under engineering supervision.

Note 2: Where only half of the conductors in each cable are carrying current, the values in the table shall be permitted to be increased by a factor of 1.4.

Informational Note: The conductor sizes in data cables in wide-spread use are typically 22 – 26 AWG.

Temperature rise correction

…when a current passes through a conductor, the conductor heats up…

Joule's law

$$\Delta T(I) = kI^2$$

In the case of cable heating, k is a function of <u>many</u> parameters including:

- *conductor resistance*
- *bundle size*
- *number of conductors energized*
- *cable construction*
- *presence of insulation*
- *etc…*

Source:
TR42.7-2015-10-158-BundledCableEvals
Wayne Hopkinson

Temperature rise correction

- For a single measurement configuration "*k*" does not change
  The ratios of currents versus temperature rises can be expressed as:

$$\Delta T_1 = k I_1^2$$

and

$$\Delta T_2 = k I_2^2$$

since k doesn't change

$$\frac{\Delta T_2}{I_2^2} = \frac{\Delta T_1}{I_1^2} = k$$

then

$$I_2 = \sqrt{\frac{\Delta T_2}{\Delta T_1}}\, I_1$$

IEEE P802.3bt™/D1.4, 26th October 2015

Table 33–1—System power parameters Vs Maximum PSE Class

System Power Limit (Maximum PSE Class)	Nominal Highest Current per pair (I_{Cable}, A)	Channel pairset maximum DC loop resistance (R_{Ch}, Ω)	Minimum Cabling Type[1]
Class 0 to 3	0.350 .175 per conductor	20.0	twisted-pair cabling per 14.4 and 14.5 (Class D or Category 5 recommended)
Class 4	0.600 .300 per conductor	12.5	Class D (ISO/IEC 11801:1995) or Category 5 (ANSI/EIA/TIA-568-A:1995)
Class 5 and 6	0.600[2] .300 per conductor	12.5	Class D (ISO/IEC 11801:2002) or Category 5e (ANSI/EIA/TIA-568-B.2:2001)
Class 7 and 8[3]	0.960[2] .480 per conductor	12.5	Class D (ISO/IEC 11801:2002) or Category 5e (ANSI/EIA/TIA-568-B.2:2001)

[1]See sections 33.1.4.1 and 33.1.4.2.
[2]In Type 3 and Type 4 operation, the current per pairset will be impacted by pair-to-pair system resistance unbalance. See section 33.2.7.4.1.
[3]For additional information, see TIA TSB-184-A.

- Coordination with TIA/ISO cabling committees on power delivery - 802.3af, 802.3at and 802.3bt – TSB-184 published 2009 and TSB-184-A in development.

- Extensive cooperative analysis of temperature rise versus current measurements and modeling between SDOs (IEEE/TIA/ISO/IEC)in development of TSB-184 and TSB-184-A

Temperature rise correction

Proposed Table [725.144] 30 degrees C ambient

	Numbers of cables						
Ambient	1	2 to 7	8 to 19	20 to 37	38 to 61	62 to 91	92 to 192
30	60	60	60	60	60	60	60
ΔT	30	30	30	30	30	30	30
26	1.00	1.00	0.70	0.50	0.40	0.40	NA
24	2.00	1.00	0.80	0.60	0.50	0.40	0.30
23	2.50	1.20	0.80	0.60	0.50	0.50	0.40
22	3.00	1.40	1.00	0.70	0.60	0.60	0.50

Proposed Table [725.144] corrected to 45 deg C ambient constrains bundle sizes to <19 cables

	Numbers of cables						
Ambient	1	2 to 7	8 to 19	20 to 37	38 to 61	62 to 91	92 to 192
45	60	60	60	60	60	60	60
ΔT	15	15	15	15	15	15	15
26	0.71	0.71	0.49	0.35	0.28	0.28	NA
24	1.41	0.71	0.57	0.42	0.35	0.28	0.21
23	1.77	0.85	0.57	0.42	0.35	0.35	0.28
22	2.12	0.99	0.71	0.49	0.42	0.42	0.35

•Proposed Table [725.144] correction to 45 deg C is inconsistent with TIA-184-A limiting cable bundle to up to 19 cables except for 22 AWG (<37 cables) with 0.48 A per conductor versus TIA-TSB-184-A allowances for up to 74 cables in a bundle with 0.5 A per conductor (1A per pair).

TIA TSB-184-A*

Table A.6 - Temperature rise v. cable bundle size (1000 mA per pair)

Number of Cables	Temperature Rise (°C)				
	26 AWG	C5e 1A	C6 1A	C6A 1A	Cat 8 1A
1	1.5	1.3	1.0	1.2	1.2
7	4.2	2.9	2.3	2.3	2.2
19	9.7	6.1	5.0	4.6	4.3
24	12.0	7.4	6.1	5.6	5.2
37	18.0	10.9	9.0	8.0	7.5
48	23.1	13.9	11.5	10.1	9.4
52	25.0	15.0	12.4	10.9	10.1
61	29.2	17.4	14.5	12.7	11.7
64	30.3	18.1	15.0	13.1	12.2
74	34.9	20.7	17.2	15.0	13.9
91	42.9	25.4	21.1	18.3	16.9
97	45.7	27.0	22.5	19.4	18.0
100	47.0	27.8	23.1	20.0	18.5
127	59.4	35.0	29.1	25.1	23.2
169	78.7	46.3	38.5	33.1	30.6

*Guidelines for Supporting Power Delivery Over Balanced Twisted-Pair Cabling.

Article 725.144 - Ambient Temperature Correction Factor

(2) For ambient temperatures above 30°C (86°F), the correction factors of 310.15(8)(2) shall apply.

(2) Ambient Temperature Correction Factors. Ampacities for ambient temperatures other than those shown in the ampacity tables shall be corrected in accordance with Table 310.15(B)(2)(a) or Table 310.15(B)(2)(b) , or shall be permitted to be calculated using the following equation:

$$I' = I\sqrt{\frac{T_c - T_a'}{T_c - T_a}}$$

where:

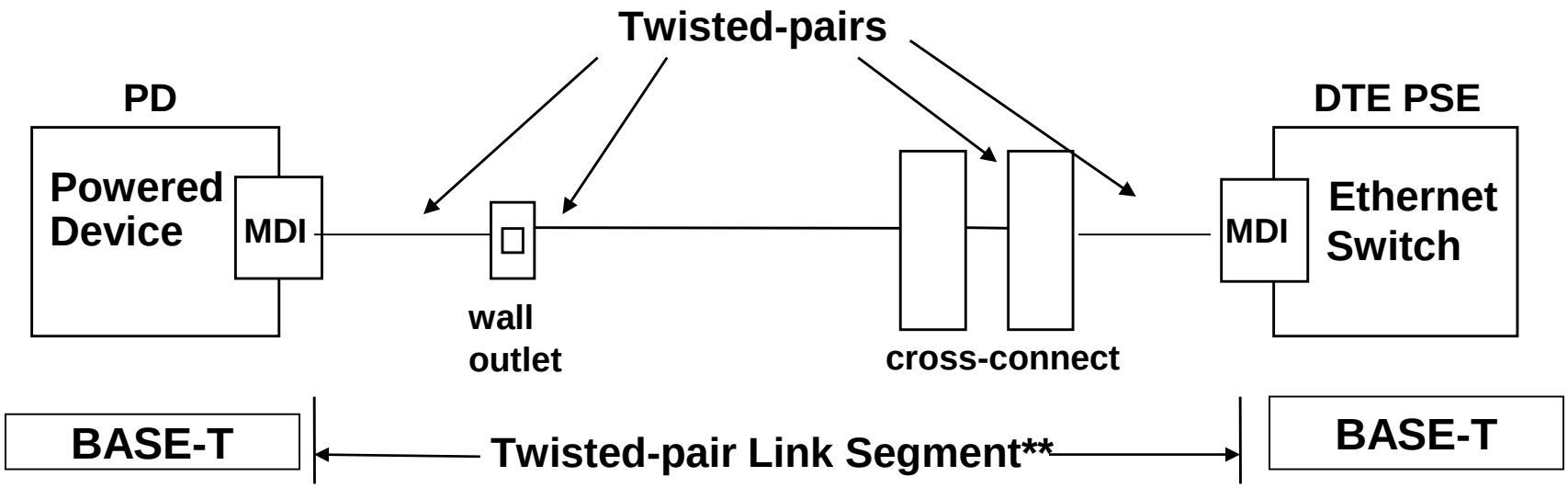
I' = ampacity corrected for ambient temperature
I = ampacity shown in the tables
T_c = temperature rating of conductor (°C)
T_a' = new ambient temperature (°C)
T_a = ambient temperature used in the table (°C)

le 310.15(B)(2)(a) Ambient Temperature Correction Factors Based on 30°C (86°F)

For ambient temperatures other than 30°C (86°F), multiply the allowable ampacities specified in the ampacity tables by the appropriate correction factor shown below.

Ambient Temperature (°C)	Temperature Rating of Conductor			Ambient Temperature (°F)
	60°C	75°C	90°C	
10 or less	1.29	1.20	1.15	50 or less
11–15	1.22	1.15	1.12	51–59
16–20	1.15	1.11	1.08	60–68
21–25	1.08	1.05	1.04	69–77
26–30	1.00	1.00	1.00	78–86
31–35	0.91	0.94	0.96	87–95
36–40	0.82	0.88	0.91	96–104
41–45	0.71	0.82	0.87	105–113
46–50	0.58	0.75	0.82	114–122
51–55	0.41	0.67	0.76	123–131
56–60	—	0.58	0.71	132–140
61–65	—	0.47	0.65	141–149
66–70	—	0.33	0.58	150–158
71–75	—	—	0.50	159–167
76–80	—	—	0.41	168–176
81–85	—	—	0.29	177–185

IEEE 802.3bt - Twisted-pair Link Segment with DTE power



Powered Device
- **VOIP Phone**
- **Wireless Access Points**
- **etc…**

**Cabling channels as specified in ISO/IEC 11801 and ANSI/TIA/EIA-568

- Cabling functionally specified over the temperature range from -10 °C to 60 °C.
  - -Temperature dependent electrical characteristics (resistance/balance, insertion loss)
  - -Connecting hardware used to terminate to 100 ohm balanced twisted-pair cabling shall be functional for continuous use over the temperature range from -10 °C to 60 °C.

NEC 2017 Timelines (my understanding)

- Letter ballot (January 4) CMP 3 and CMP 16.
- The correlating committee meets in February to reconcile drafts.
- The 2nd draft revisions are published in April.
- End of April - notice of intent to make a motion (NITMAM)
- NFPA meeting in June; voting of certified amending motions.
- After that there is the standards council – review process was followed.

Conclusion/Recommendations

•Proposed Table [725.144] inconsistent with TIA-184-A
- [725.144] cable bundle up to 19 cables with 0.48 A per conductor
- TIA-184-A up to 74 cables in a bundle with 0.5 A per conductor

•TSB-184 and TSB-184-A developed through broad based cabling and equipment manufacturer participation (IEEE/TIA/ISO/IEC).
- Extensive cooperative analysis of temperature rise versus current measurements and modeling between SDOs.

•Cabling/Link Segment electrical/mechanical performance not considered when operating > 60 deg C per [725.144].
- DC resistance and insertion loss temperature corrections.

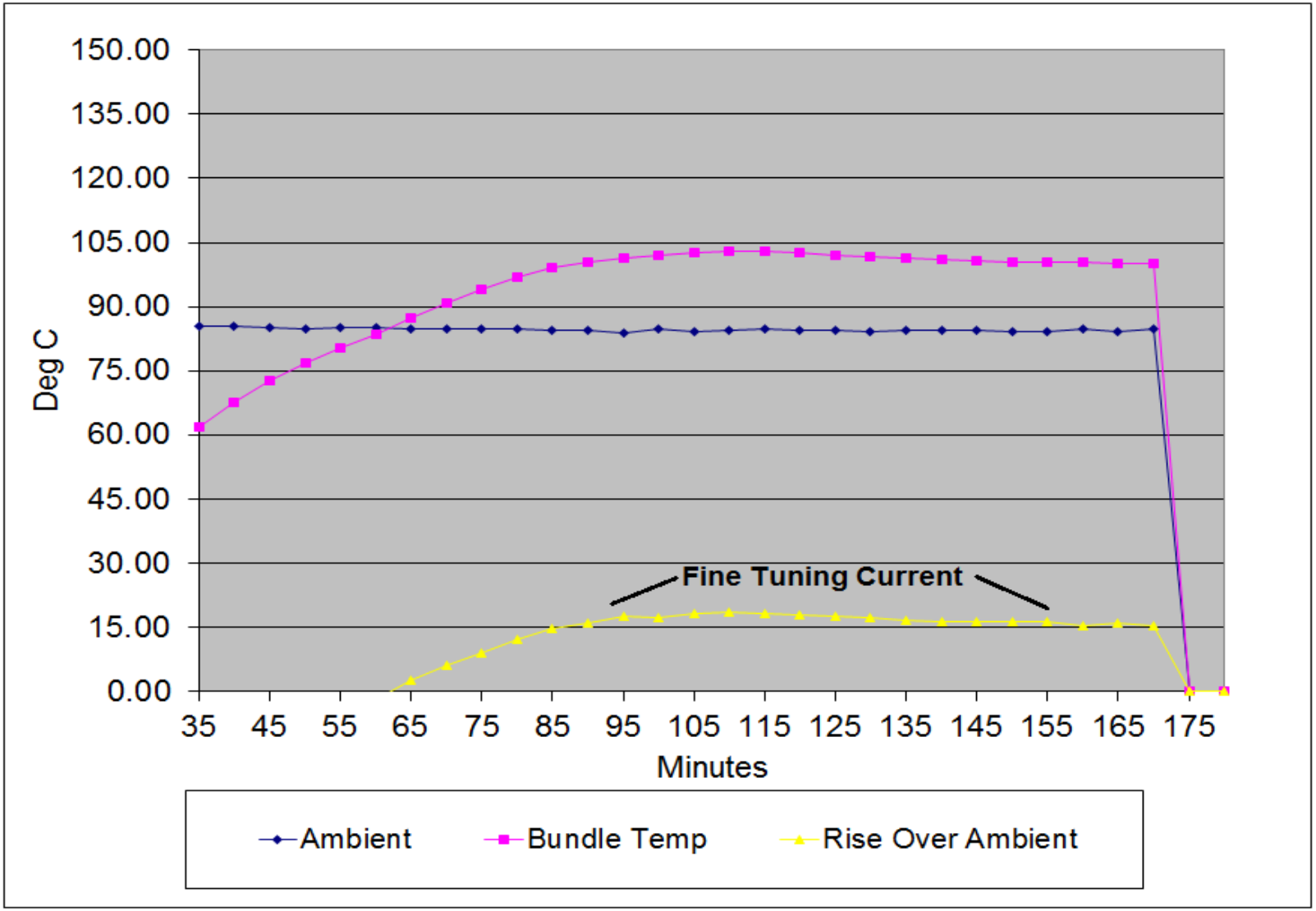
- Recommend that the IEEE 802.3 WG continue to liaise with CMP 16 and CMP 3 during the NEC 2017 revision process to reaffirm that these changes to the code are premature and should be deferred to the 2020 code revision cycle permitting sufficient time for all interested and affected parties to review and comment.
  - Review of Table [725.144] current limits and operating temperatures.
  - Review specifications and availability of the referenced LP cabling.
  - TIA/TR42.7 Task Group chartered to consider differences in TSB-184-A and Proposed Table [725.144]; to include test methodologies and configurations.

Supplemental

Elevated temperature testing of 60 deg C rated cable

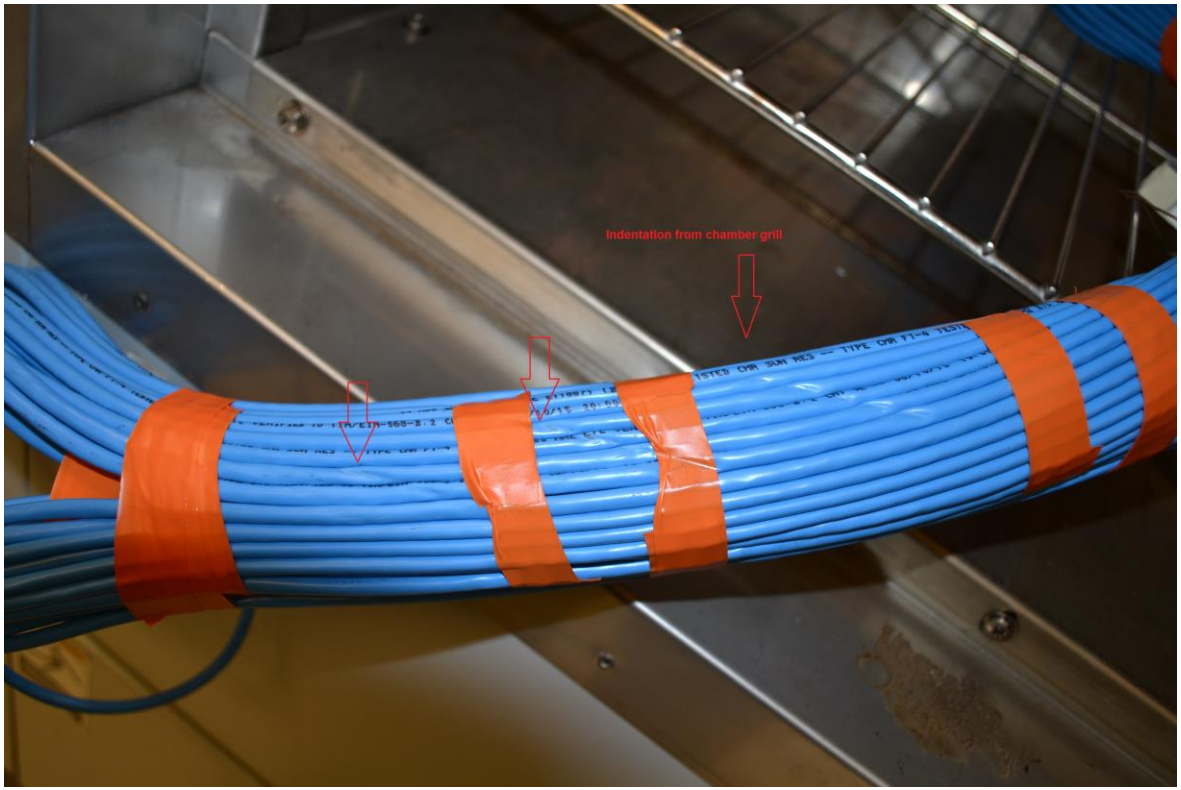
- Obtain 60 deg C rated cabling from home improvement store.
- Loop 90m into bundle and test PL for performance.
- Place in oven to raise ambient to 85 deg C.
- Add current to heat center cable of bundle to 15 deg C over ambient.
- Soak for 1hr.
- Remove, cool, and retest for performance.

Temperature Profile



Cable – Post 100 deg C

-Maintained continuity
-More rigid

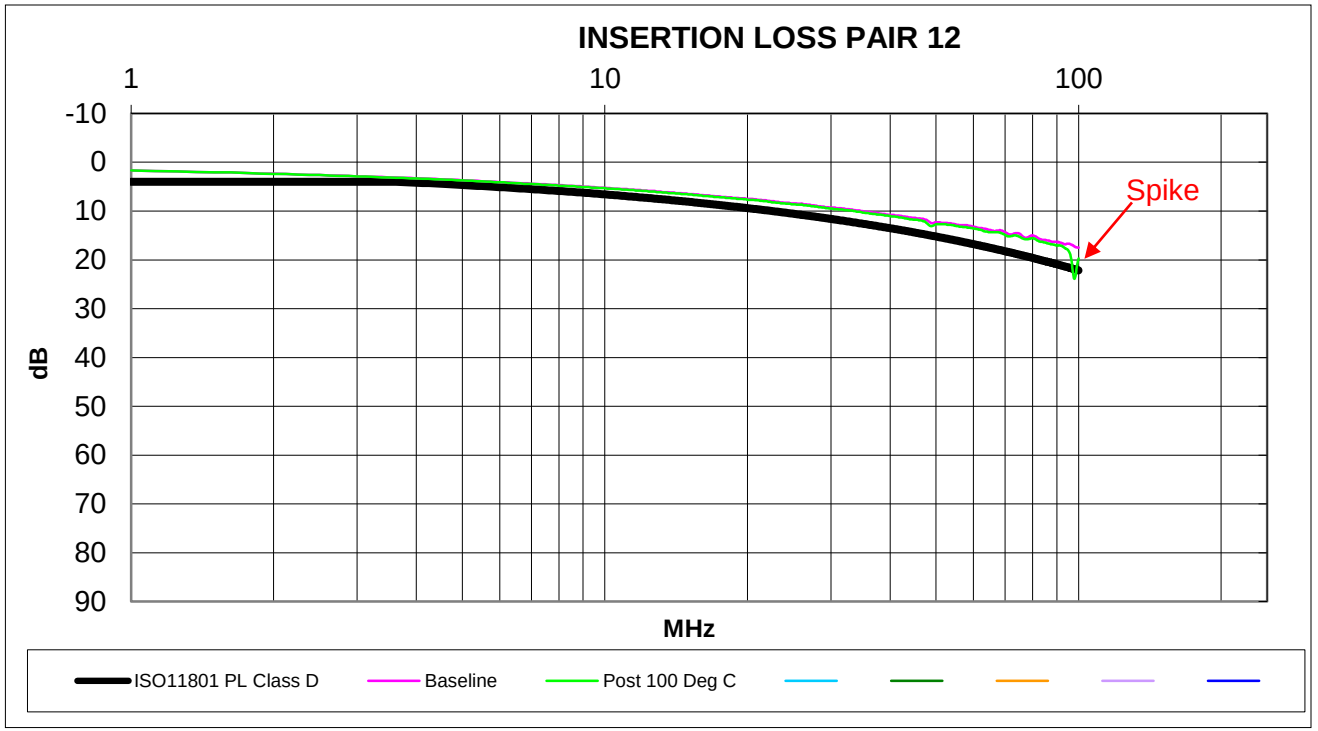


Electrical Performance

-Occurred on all pairs
at the same freq
-Mag of spike was almost
5 dB more severe on
12 & 78 vs 45 & 36

(Note: 12 & 78 are loosest twist rate)

Baseline		Post 100 Deg C	
MHz	dB	MHz	dB
100.0	4.65	98.0	-2.00



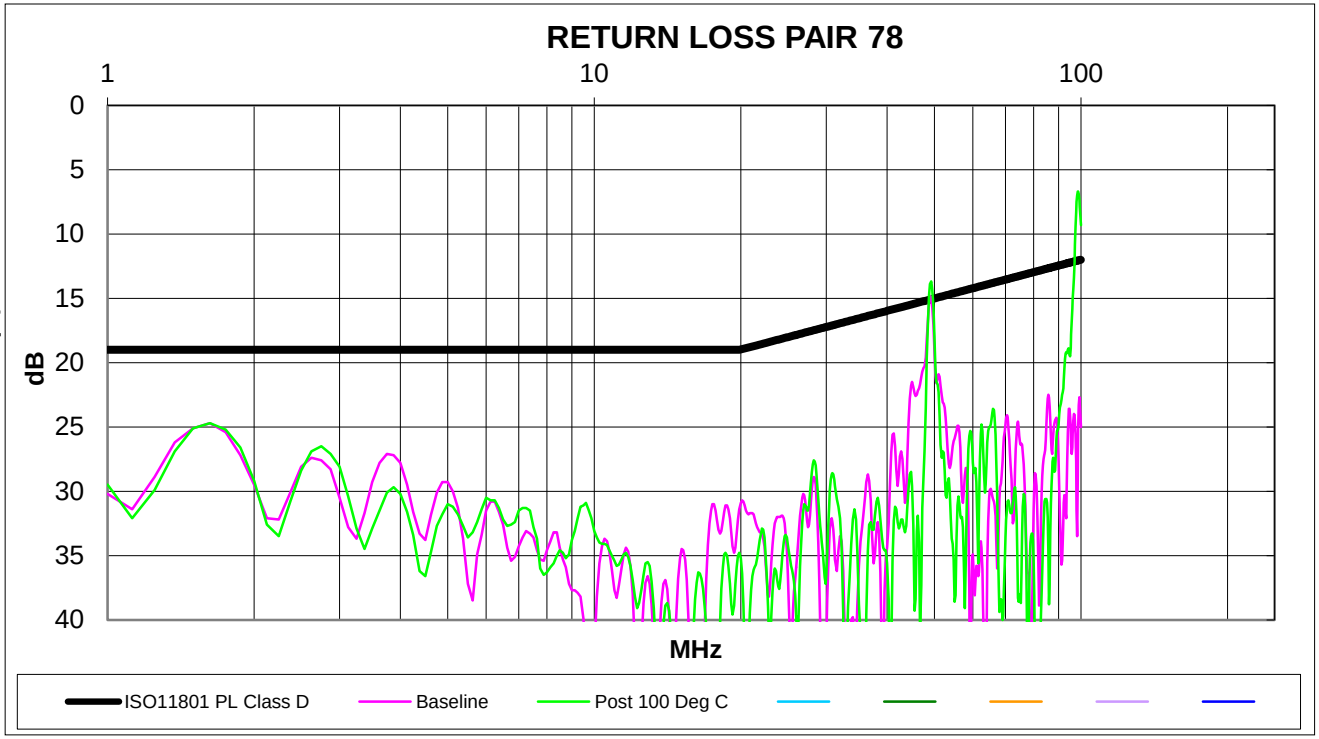
Electrical Performance

Baseline		Post 100 Deg C	
MHz	dB	MHz	dB
49.0	-0.3	98.5	-5.4

-Occurred on all pairs at the same freq

-Mag of spike was almost 3-4 dB more severe on 12 & 78 vs 45 & 36

(Note: 12 & 78 are loosest twist rate)



Summary – elevated temperature

- Residential grade cabling experienced temperatures in excess of 100 deg C and still provided adequate channel performance.
- No safety concerns of fire, smoke, shorts, or toxic odors were experienced.