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Next Generation PoE

The New Power over Ethernet Standards Deliver More Power, Speed, and Efficiency

The TEK Center
TECHNOLOGY • ENGINEERING • KNOWLEDGE

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For over a decade, Power over Ethernet (PoE) and PoE+ provided organizations with a simple and convenient option for powering devices such as IP phones and low-power cameras. Now, as IP technology connects seemingly all aspects of our everyday life, structured cabling is being used to support an increasingly diverse and power-hungry set of devices. This paper looks at the new codes and standards recently released, the emerging deployment arenas and their respective applications. Further discussions on the impact to structured cabling, and insights to enable planning of cabling infrastructure deployments supporting the new PoE power levels now available are also provided. It is clear that the PoE ecosystem will continue to grow through new applications and will be better serviced by cabling with improved power delivery capabilities.

The Evolution of PoE

PoE first emerged in 2003 with the IEEE 802.3af standard and was originally built around Category 3 and Category 5 specifications, to deliver approximately 13 watts to a powered device through 350mA of current with Ethernet speeds up to 100Mbps. The standard allowed for delivering power on two combinations of two pairs as two different alternatives – Mode A or Mode B (**Figure 1**). However, the standard did not permit power simultaneously over all four twisted pairs. In Mode A, pairs 1-2 and 3-6 have both power and data flowing over them while pairs 4-5 and 7-8 are unused. In Mode B, all pairs are utilized, but power and data are separated, with data being carried via pairs 1-2 and 3-6 and power using 4-5 and 7-8.

In 2009 major changes were made to PoE with the ratification of IEEE 802.3at. These included specifying Category 5 cabling as the minimum cable grade required to support the new PoE+ standard. With this ratification, 25.5 watts and 600mA of current could now be delivered to devices. As illustrated in **Figure 2**, all four pairs are utilized to transmit data to support 1000BASE-T transmission, but Mode A and Mode B power distribution remains consistent with the previous standard.

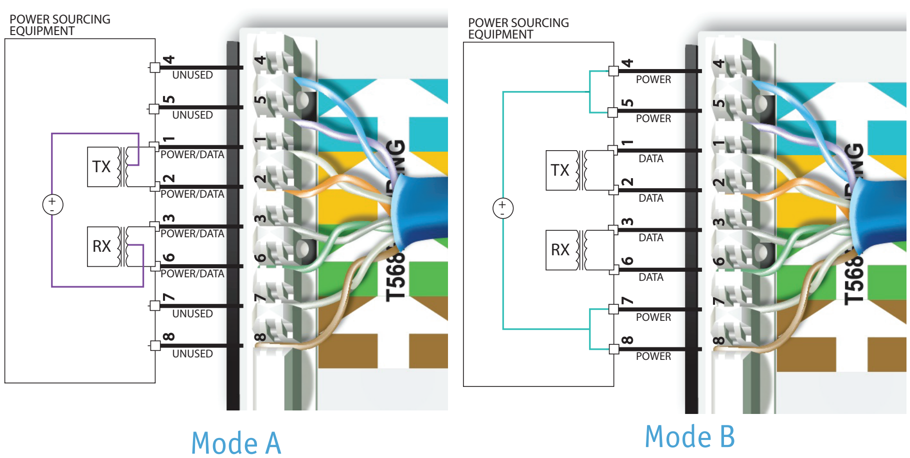

Figure 1: *802.3af delivers 12.95W and 10/100BASE-T*

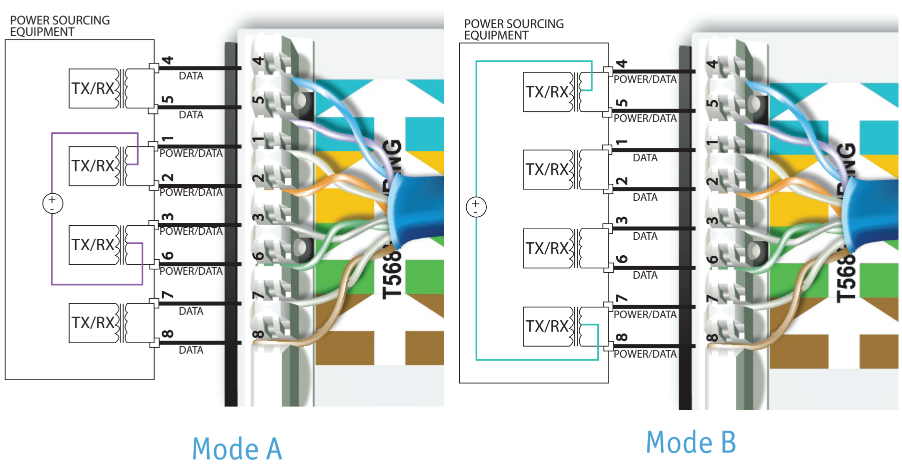

Figure 2: *802.3at delivers 25W and 1000BASE-T*

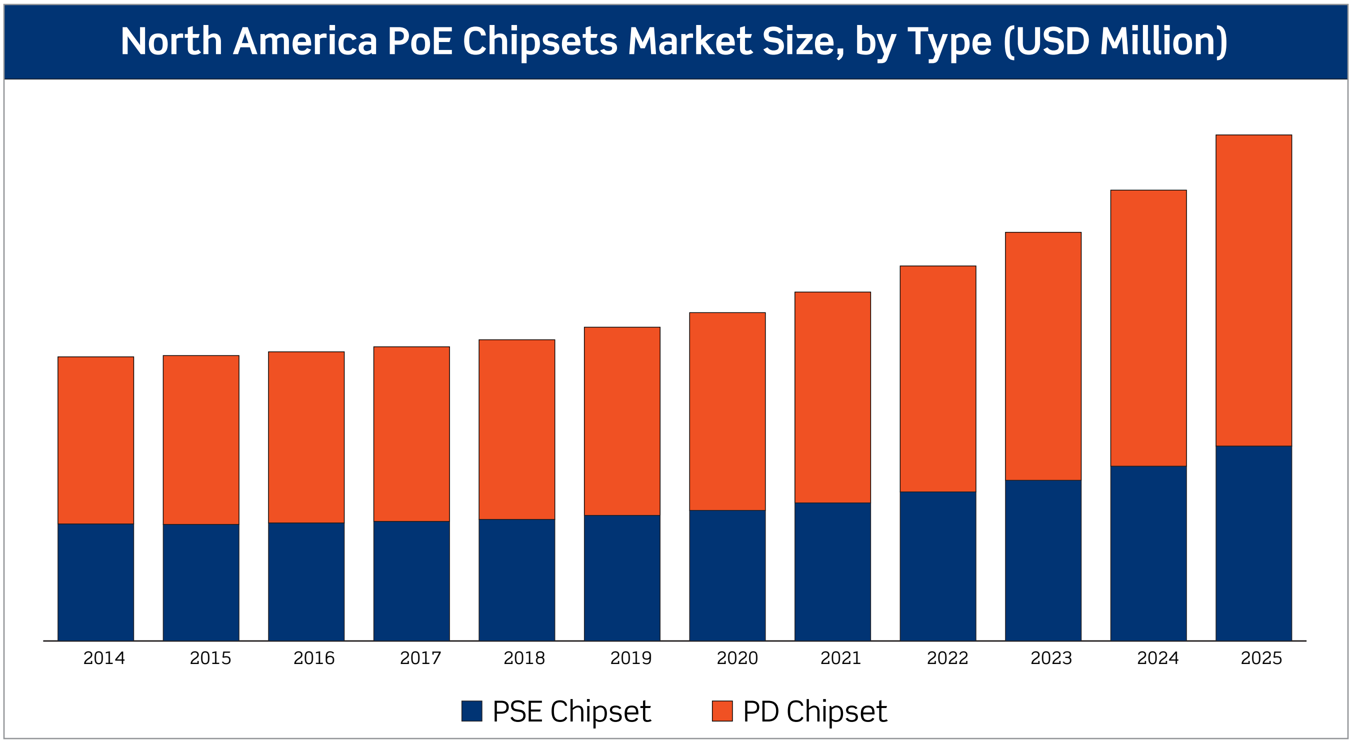

Figure 3: *High Power PoE Applications*

Enhancements for Emerging Applications

In the intervening years since the 802.3at ratification, non-standardized solutions have been developed to address specific challenges. For example, some solutions deliver continuous power without the IEEE specified handshake or perhaps require additional converters at the device. Others deliver 50 watts over four pairs, maintain compatibility with 802.3at, and yet are not 802.3at standards-compliant due to the explicit exclusion of 4-pair power delivery. Finally, there are the proprietary solutions that deliver higher wattages but are not compatible with the current standardized equipment.

In March 2013, the IEEE held a Call for Interest focused on evaluating the need to develop a higher power standard. This need was driven primarily by emerging applications that require power in excess of 25 Watts. The markets with identified needs included areas such as healthcare, retail, building management, IP turrets, thin clients, video conferencing, IP security cameras, and industrial networks. **Figure 3** above depicts the overall potential market for high power PoE ports, with especially substantial growth in building management opportunities through 2025. Significant growth is also projected for industrial automation and thin clients.

Setting the Stage for Next Generation Standards

As the need for more power increased, so did the expectation of standardization, which centered primarily on delivering as high a power output level as could be managed. It also required increased system efficiencies to address the limitations of a DC power distribution system. Early generations of the new generation of PoE networking equipment lacked power reserves and were unable to provide the full 25 watts of power across all ports simultaneously, causing issues with large scale deployments. This power supply limitation would need to be mitigated by provisioning greater capacity and smarter equipment designed to dynamically allocate power. The new standard also needed to additional Ethernet devices such as 802.11ac wireless access points that require additional power as well as faster network speeds.

To address this, the IEEE 802.3bt task force convened in January 2014 to begin the standardization process of the next generation of PoE. Comprised of electronic component and cabling manufacturers, the task force had the responsibility of specifying new levels of power delivery while assuring compatibility with previous generations of equipment. As an example, Cisco's

UPOE delivering 60W needed to be compatible when the task force released the new standard. It was decided that to create this efficiency power would be delivered over all four pairs as

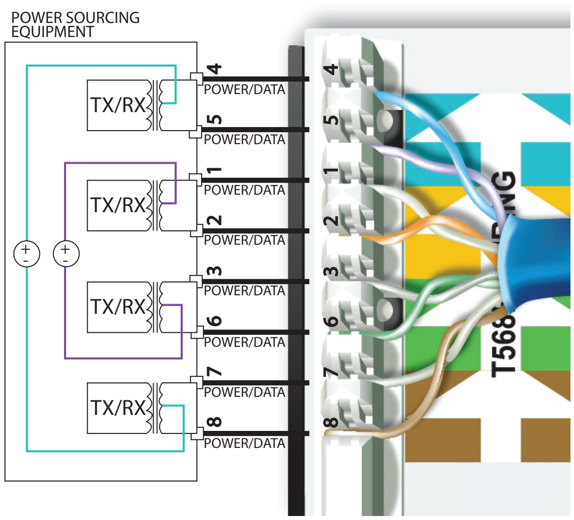

Figure 4: *Four-pair power delivery*

shown in **Figure 4**. The use of all four pairs increased efficiency by cutting the potential delivery losses in half.

With the publication of the IEEE 802.3bt standard in September of 2018 PoE can now support a significant number of new devices and network speeds while remaining backwards compatible with the previous generations of the PoE standards, IEEE 802.3af and 802.3at. The new standard supports 10GBASE-T operation as well as 2.5Gbps and 5Gbps to connect the latest 802.11ac wireless access points that are aggregating the traffic of multiple users and multiple devices.

The initial objective of delivering a minimum of 49 watts to the powered device was adopted in order to deem the project successful. However, the standard ended up supporting many different power levels. The standard recognizes two primary active components in the system. The power sourcing equipment (PSE) represents the end span switches or mid-span injectors while the powered device (PD) represents the device at the opposite end, such as a camera, thin client, or building management device.

There are 9 classes of PSE providing power levels ranging from 4 watts to 90 watts, as illustrated in **Table 1**. Due to cabling losses over a maximum of 100 meters, the available power at the PD is slightly less. *(Note: Class 0 and Class 3 are grouped together because they are required to deliver the same 13W to the powered device. Class 0 can be declared or used as a default state when the powered device does not indicate its classification. It is presumed that an undeclared device will need the maximum 13W.)*

Table 1: Power Sourcing Equipment Classifications

Class	Min Power from PSE (Watts)	Min Guaranteed Available Power at PD (Watts)
0 and 3	15.4	13.0
1	4.0	3.84
2	7.0	6.49
4	30.0	25.5
5	45.0	40.0
6	60.0	51.0
7	75.0	62.0
8	90.0	71.3

In order to further maximize power delivery, the standard takes into account the power levels required to overcome the cabling losses in each link. Specifically, in the case of short links, the PSE may conserve and repurpose the unused power for other links, or allow a PD on a short link to reserve and utilize the unused power that is budgeted for a full 100-meter length deployment. These system design characteristics give added importance to the development of cabling specifically designed for use in multiple applications with the goal to improve overall system efficiencies. For the delivery of power and data, higher grades of cable, or cables with larger conductors will provide the best performance and efficiencies.

Understanding the Power-Heat Relationship

While the IEEE standard was in development, several manufacturers and technical consortiums worked to evaluate the thermal impact of delivering almost 100 watts of power over 4-pair cables. It was apparent that increasing power delivery increases current flow, resulting in an increase in heat generation within the cabling infrastructure. Increased power delivery can significantly impact cable bundle temperatures depending upon the construction of the cable. As a result, the standards bodies of TIA, ISO and CENELEC investigated the impact of delivering an average of 1 amp per pair within the cable and establishing installation recommendations accordingly. Modeling and installation recommendations were published in TIA TSB-184-A: Guidelines for Supporting Power Delivery over Balanced Twisted-Pair Cabling and additional guidelines were added to the second addendum of TIA 569-D: Telecommunications Pathways and Spaces: Addendum 2 – Guidelines for Supporting Remote Powering.

In general, cable temperature rise with PoE deployment is a function of several factors:

1. Gauge Size: Larger copper conductor reduces the resistance and allows for easier current flow, generating less heat.
2. Twist Rate per Inch: Higher categories of cable generally have increased pair twist rates. This increased twist rate creates a longer electrical path per given cable length, as depicted by Pair A in **Figure 5**. This results in increased resistance to current flow and increased heat generation.
3. Current: As current increases, so does heat generation.
4. Thermal Insulation/Diffusion: This refers to the ability to shed or disperse the generated heat to the outside environment. Cables unable to cool will increase in temperature until equilibrium is reached.
5. PoE Deployment Density: Heat generation increases as the number of PoE drops increase within a pathway.

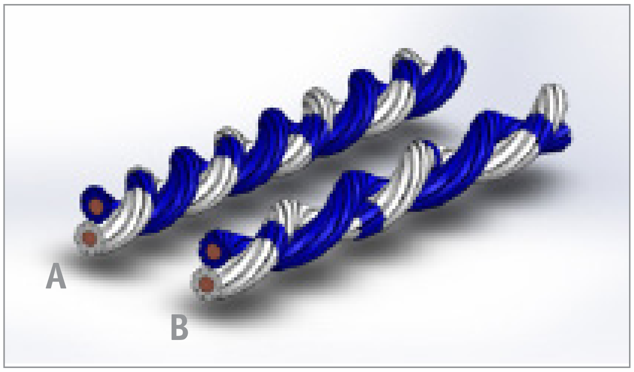

Figure 5: *Increasing twists (Pair A vs. Pair B) increase DCR*

The Impact of Higher Power on Cabling

There are three major reasons for an interest in heat: environmental heat loading to the facility, safety, and the impact to electrical performance.

Environmental heat loading

This can be a fairly straightforward calculation as it is based upon the number and length of the drops in conjunction with the cable's DC resistance and electrical current traversing the pairs. Deploying large amounts of high power PoE may increase the HVAC requirements for some parts of a facility and raise the average ambient and peak temperatures experienced by the cabling.

Safety

Cable heating due to PoE power deployment may cause the temperature inside a large bundle to age at a faster rate, and the jackets and insulation materials may become brittle when exposed to these elevated temperatures for extended periods. This may result in cracking or segments of insulation falling off the cable. Flame retardant properties may also be reduced as vital components within the compounds degrade or evaporate. Cables commonly have temperature ratings, such as 60 or 75°C, which are designed to ensure their safe operation over their lifetime. Failing to account for thermal gain from PoE deployments may increase the temperature of a cable bundle above its safety listing when installed in a hot environment. Given the potential for increased heat generation that comes along with it PoE deployment, those specifying cabling infra-structures should consider cabling with a listing temperature of 75°C or higher, particularly for those areas with an already elevated ambient operating temperature.

Electrical Performance

Increased operating temperatures can also increase the insertion loss of the cable potentially reducing the effective reach of copper cabling, making a full 100-meter reach with minimally compliant cable unobtainable for some bundles at the highest power levels. Therefore, ambient conditions as well as thermal gains from PoE must be considered designing the cabling layout. Channel length reductions, or bundle size reduction through pathway selection may be necessary to achieve the reach desired.

Testing that Replicates the Real World

The complexities of real world installations create an infinite number of possible test scenarios. Today's LAN cables are subjected to a wide range of installation conditions, such as extremely large bundles, packed cable trays and conduits. Care must be taken not to underestimate the impact of cable heating due to increased power delivery.

To accurately determine temperature rise due to PoE on different cable types the TEK Center at Berk-Tek recently published a Test Report entitled Next Generation Power over Ethernet and Temperature Testing. This report examines temperature rise when power is applied to different cable types in open and closed trays, in addition to cable inside conduit. Several different cable manufacturers products were used, and the cable types included Category 5e through Category 6a. To avoid confusion, this paper will focus on one representative product from each category tested:

- Category 5e: LANmark-350™
- Category 6: LANmark™-1000
- Category 6A (unshielded): LANmark™-10G2
- Category 6A (foil-isolated): LANmark™-XTP

The testing focused on two bundle sizes of 37 and 259 cables. The quantity 37 (depicted in **Figure 6**) was selected to match testing being done by the industry standards bodies, and because of its approximate size to cable bundles servicing 24 and 48 port panels.

The 259-cable bundle was built from seven bundles of 37 as depicted below in **Figure 7.** It should be noted that this bundle would closely approximate the deployment of 240 cables addressing ten fully populated 24-port patch panels. All bundles were subjected to currents representing the various power levels available for PoE deployments, and the resultant temperature increases were measured. Thermal increases were calculated by measuring the temperature increase of the inner-most cable after the bundle reached equilibrium (6-8 hours) and comparing it to the recorded ambient temperature.

These results were compared to a TEK Center mathematical model for predicted heat generation. **Figure 8** (on the next page) represents the comparison of the highest temperature rise of the various cable constructions with respect to the size of the bundle when carrying 1000mA of current across each pair, which closely approximates the conditions of Class 8 power delivery. The model provides a high degree of correlation between the measured and predicted data in this test configuration.

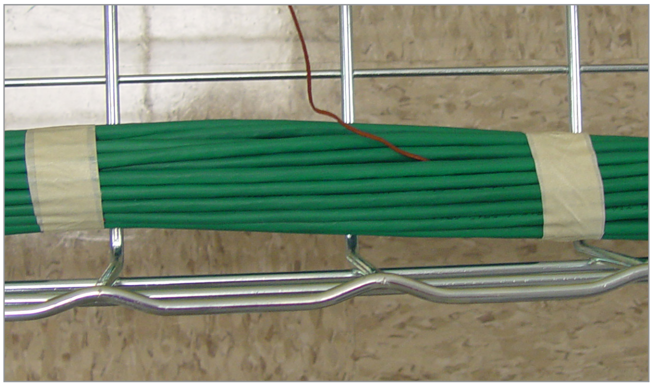

Figure 6: *A 37-cable bundle under test*

The data and the model both tell us some important things about how specific cable types will react to PoE power Specifically, the TEK Center's testing showed:

1. Higher category cables experienced less temperature rise than lower category cables.

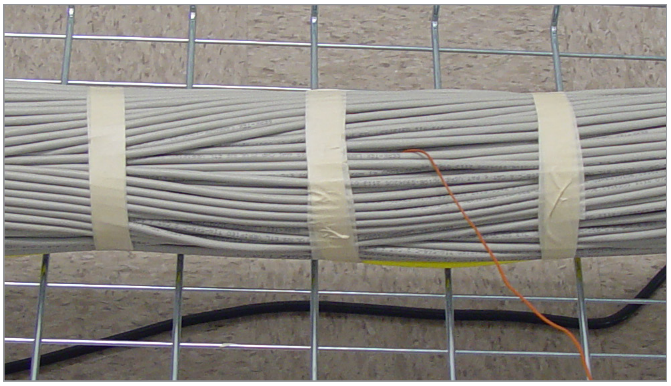

Figure 7: *A 259-cable bundle under test*

2. In larger bundles, LANmark-10G2 (Category 6A UTP) performed similarly to LANmark-1000 (Category 6AUTP). This is attributable to the construction of a Category 6A UTP cable, specifically its higher twist rate and increased jacket thickness, both of which are needed to meet internal and external crosstalk requirements.

3. In this evaluation the best performance was exhibited by the foil isolated Category 6A product, LANmark-XTP. The XTP cable exhibits significantly less temperature increase with 1000mA per pair power delivery than any of the other cable designs. In a 259-cable bundle, the XTP cable is approximately 18°C (32°F) degrees cooler than the LANmark-350 Category 5e cable. This is a significant difference and will become even more critical as more devices demand the highest levels of power delivery over the network. This reduced temperature rise with the XTP cable reinforces its suitability to high power PoE deployment as it helps to ensure the cable reach is maximized under adverse conditions.

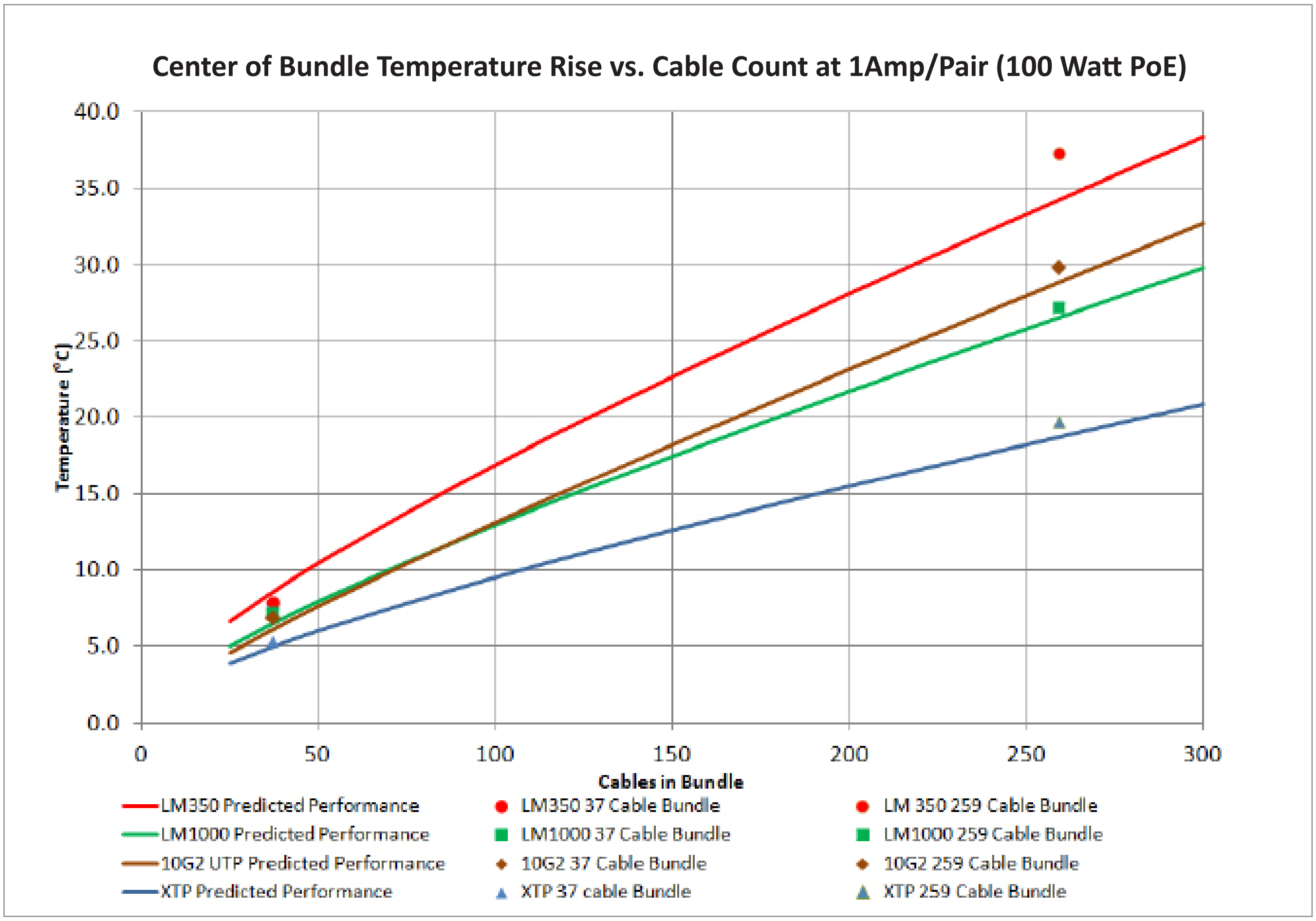

Figure 8: *Modeled vs. measured temperature rise of innermost cable in bundle in an open tray*

The TEK Center conducted a second series of tests to determine the effect of conductor size on the thermal performance of bundled cables carrying power. The testing was done using Berk-Tek's Hyper Plus 5e and LANmark-6 UTP cables constructed with 24 AWG conductors and Berk-Tek's LANmark-IP Category 5e UTP cable which is constructed with 22 AWG conductors. Each cable type was assembled into bundles of 192 cables in open air. The resulting temperature increase for each cable type is shown in **Figure 9**.

The temperature rise of the 24 AWG Cat 5e cable starts to increase at a similar rate at 0.3A per conductor, but the temperature of the Cat 6 cable, with its larger 23 AWG conductor rises more slowly than the 24 AWG Cat 5e cable as the power level is increased. However, temperature rise in the LANmark-IP Category 5e cable bundle is much lower than the other cables at each power level due its larger 22AWG conductors. These results show that for devices requiring higher power levels, but data rates of 1Gbps or less, such as PoE lighting, a purpose-built Cat 5e cable with larger conductors is a good option.

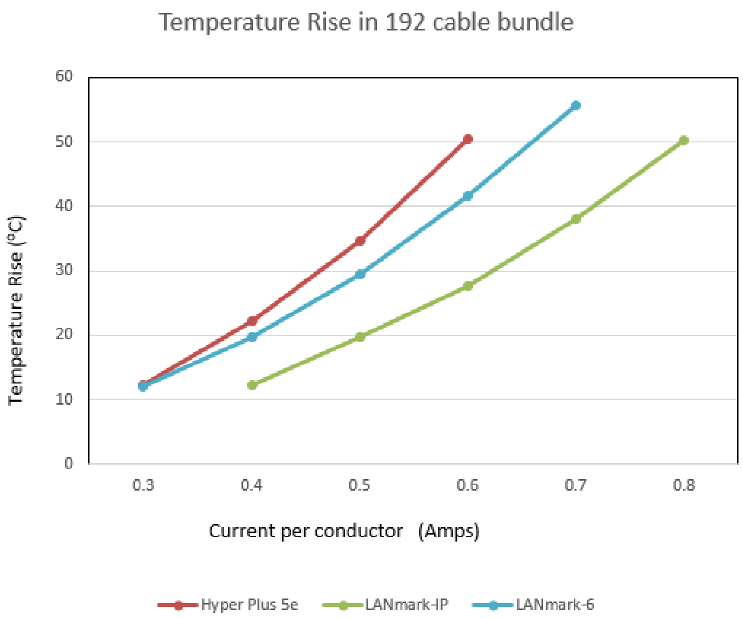

Figure 9: *Temperature rise for each cable type in 192-cable bundle.*

PoE Impacts to Installation Methods

To address the safety aspects associated with the potential rise in temperature of large cable bundles carrying PoE the Telecommunications Industry Association (TIA) and the National Fire Protection Association (NFPA) have the codes and standards that govern the installation practices used to install cabling systems.

The TIA has issued TSB-184A as a revision to the original TSB-184 to outline the recommendations for mitigating the potential heating effects of PoE in cable bundles. Included in this document is the recommendation that Cat 6A cabling be used when planning to support Power over Ethernet. Table A.6 of the document assumes an ambient installation temperature of 45°C and a standard cable listing temperature of 60°C, thus allowing for a maximum cable temperature increase of 15°C due to PoE heating. The document provides the bundle size recommendations listed in **Table 2** for different gauge sizes and cable types supporting various power levels.

In addition, TSB-184A also provides recommendations for areas where large amounts of cable are routed through a common pathway to limit the heating effect of PoE on these cables. These recommendations include the instruction to disperse unbundled cables throughout an open wire basket tray to allow airflow for cooling effectiveness. It also allows for the use of smaller bundles that are physically separated in the cable tray to enhance heat dissipation.

The NFPA addressed the potential for temperature increase due to PoE in the 2017 version of the National Electrical Code (NFPA 70).   Added to Part VI of Article 840 "Premises Powering of Communications Equipment over Communications Cables" Article 840.160 requires that any communication cable that will supply power to the communications equipment of greater than 60 Watts, the communication cables and the power circuit shall comply with 725.144 where communication cables are used in place of Class 2 and Class 3 cables.

Table 2: Table A.6 from TSB-184A - Maximum Bundle Size for 15°C Temperature Rise at 45°C

	26 AWG		Category 5e		Category 6		Category 6A	
	Air	Conduit	Air	Conduit	Air	Conduit	Air	Conduit
600mA	124	68	191	129	252	182	313	242
720mA	75	39	121	79	163	114	203	151
1000mA	28	13	51	31	72	46	90	62

Article 725.144 includes information on the ampacity of the conductors based on their gauge size. It contains a list of cable bundle size restrictions according to the AWG, ampacity (power level) and temperature rating of the cable. The maximum bundle size allowed in table 725.144 is 192 cables. This article also includes information on cables marked with an "LP(0.xA)" in the cable legend. The X in the marking indicates the power level per conductor (in Amps) for which that cable is rated, as certified by a nationally recognized test lab (like UL). 725.144 (B) includes an informational note that appears to allow the installation of "LP" marked cables to support the designated power level in the cable's marking without a limitation on the bundle size. Because informational notes are not normative parts of the code, there is still much discussion on whether LP marked cables can be installed in bundle sizes larger than 192. The best practice is to install cables in an unbundled state, make bundles as small as possible, and ensure that pathways are open to allow for airflow.

Conclusion

As the ecosystem of powered devices continues to grow, power delivery and heating characteristics will soon join other traditional cable performance parameters as a factor in the selection of cabling. Cabling must be able to ensure the delivery of increasing power and data speeds in adverse conditions over its expected lifetime. To maximize the capabilities and efficiencies of tomorrow's system, the correct cabling infrastructure will need to be implemented.

Selecting a higher grade of cabling, or cabling with a larger conductor, will reduce heat generation within the cabling infrastructure, minimize the impact to IP traffic traversing the network and reduce the aging effect that heat can have on insulating materials. Over time, as more devices are connected and powered over the network infrastructure, the selected solution employed in the network will have a growing impact on network performance. Cables with temperature listings of at least 75°C will be better suited to resist the aging impacts of elevated ambient temperatures over time. It is important to think about the expected lifespan of the network infrastructure, and the total lifecycle costs of selecting one option over another. In the vast majority of network IT projects, the cabling cost is negligible relative to the total project costs. Yet it can have a very significant impact on your network's performance for years to come.

Finally, foil-insulated cables such as the Berk-Tek LANmark- XTP, and cables with 22 AWG conductors such as Berk-Tek LANmark-IP will provide increased robustness with the best deployment options for PoE due to the minimized thermal gains inherent in their design. Metallic tape on the XTP product allows heat to transfer out of the cable much more efficiently than cable designs without this type of construction. This will allow for maximum ease, performance and flexibility when planning for PoE deployment. The LANmark-XTP product has been specially designed to be Berk-Tek's best performing product for high speed PoE applications. For support of applications and equipment requiring 1Gbps of bandwidth or less, the LANmark-IP cable provides power delivery efficiency and minimizes heat rise while providing an economical option for these systems.

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This stamp certifies that all testing was performed, reviewed, and approved by highly trained, experienced engineers dedicated to studying and developing solutions for future network infrastructures.

Located in New Holland, Pennsylvania, The TEK Center at Berk-Tek is comprised of several labs and a technology showcase. By employing industry-leading research, advanced testing procedures, and sophisticated modeling for emerging technologies, the applications and system labs translates expanding network requirements into leading edge cabling solutions that perform beyond the standard. Similarly, to exceed your expectations in real world applications, the materials lab develops advanced proprietary materials and process technologies that result in superior application performance that you can see and hear. The technology showcase displays the results of these labs along with industry-available equipment shown in actual segment usage, such as data center, security, and enterprise spaces. The TEK Center is a part of an extensive global R&D network with similar laboratories found throughout Nexans Inc.