POWER OVER ETHERNET

Power over Ethernet: A Consumer Centric Development Perspective

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INTRODUCTION

Power over Ethernet (PoE) has been highlighted recently with promises of more power delivery for the sophisticated applications being developed. Its definition, requirements and output have been a large focus of many organizations including the Telecommunications Industry Association (TIA), the Institute of Electrical and Electronics Engineers (IEEE) and the International Electrotechnical Commission (IEC). However, with new information established each passing month, it has become difficult to maintain a good understanding.

TODAY'S POE LANDSCAPE

	IEEE 802.3af (PoE)	IEEE 802.3at (PoE+)
Maximum Power at Power Sourcing Equipment (PSE)	15.4W	30.0W
Delivered Power to Powered Device (PD)	12.95 W	25.50 W
Allowed PSE Output voltage	44-57 VDC	50 – 57 VDC
Maximum DC cable current	350 mA per pair	600 mA per pair

Table 1: 802.3 standard power allocation and current requirements

In 2003, PoE was launched when IEEE issued 802.3af, allowing 12.95 watts to be delivered to a device through an Ethernet cable. This became the preferred choice for several devices such as Voice over Internet Protocol (VoIP) and IP cameras. These applications, however, were limited to low-power devices due to the maximum power output of which this protocol is capable. To include several emerging applications at the time, including 802.11n wireless and more sophisticated IP cameras, IEEE developed 802.3at in 2009, which not only addressed the power issue, but also created protocols to allow for continuous power negotiation to the device.

In the recent years of more sophisticated home and office devices such as cloud-integrated smoke alarms, thermostats, and IP cameras, the need for increased power delivery becomes more important to these devices that also require connectivity. IEEE is now under significant pressure from the industry to further advance the standards available to meet the new demand. In response, they are in the process of developing another revision to the 802.3 standards named 802.3bt in which the defined power delivery is expected to increase to at least 49 watts from the previous maximum of 25.5 watts. Current trends are leaning towards having all eight conductors delivering power, mimicking Cisco's UPoE system, while still carrying signals onto the edge device. By using this configuration, it is possible to double the power output of existing equipment. In addition, the proposed 802.3bt standards go one step further to classify a system with a power output between 60 and 100 watts.

HIGH-POWER POE

When considering a major increase in power, many key considerations have to be reevaluated and verified. In order to go from a four-pair 60-watt output to a 100-watt output, the current load changes from 600mA/pair to 1000mA/pair when the voltage of the PSE is kept at 50 volts. At such a drastic current capacity change, issues such as heat generation, power losses and safety protocols at the equipment end need to be studied. These issues may also lead to secondary problems that require additional analysis. Heat generation, for example, can be a serious issue for cables as highlighted in the figure below.

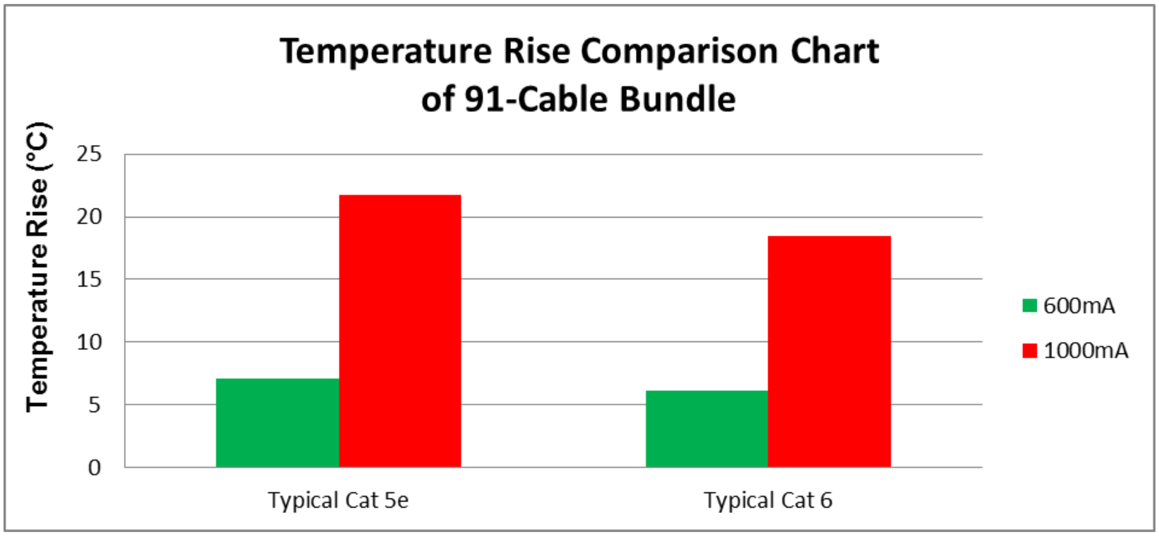


Figure 1: Comparison chart of 600mA/pair versus 1000mA/pair on typical category 5e and 6 cables. Note that this is the heat rise over ambient temperature.

Due to concerns about increased temperature rise, IEEE commissioned TIA to not only define the expectations and details of the new PoE system, but also the peak operating parameters and equipment requirements. The excess heat generated from cabling systems not designed for the increased power consumption can cause heat-aging degradation of the insulation and cable, as well as attenuation issues in data transmission.

CLARIFICATION OF NATIONAL ELECTRICAL CODE (NEC) GUIDELINES ON LIMITED-POWER CIRCUITS[1]

As power needs and capabilities increase, it is important to consider what levels of power are permitted under the electrical code. There have been questions raised about the requirements in UL 60950-1 and UL 62368-1 relating to limited-power circuits (circuits supplied by a 60950-1 or 62368-1 Limited Power Source [LPS]) and their use in Local Area Network (LAN) cable powering schemes such as PoE, Power over HDBaseT (PoH) and the like. In particular, the permitted use of multiple limited-power circuits at a port (connector) or in a cable has been the subject of much discussion.

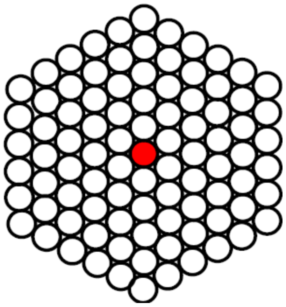
Limited-power circuits are permitted as a power source for Class 2 circuits under NEC Article 725.121(A)(4). The UL 60950-1 limited-power requirements apply to “individual circuits.” So, if an output port has four circuits, potentially four times the limit (e.g., 400 watts if the circuit limit is 100 watts as it is for limited-power circuits) could be associated with the port. This application has been associated with 60950-1’s limited-power requirements from the beginning, and it is also supported by UL 62368-1 and “Hazard-Based Safety Engineering” (HBSE) principles where the energy of individual circuits is the key aspect for characterizing circuits, not the accumulation of energy of different circuits that may or may not be interconnected. This is not to say that the accumulation of energy from different sources can be ignored, only that the characterization of the individual circuits and their risk of fire does not change until the circuits are interconnected in such a way that the power exceeds the individual limits.

Even if the individual circuits are kept separated at the ports and within the cable, “port summing” in the powered devices is something to which attention needs to be paid, and is as part of the certification of equipment. The sum of individual circuits that may be handled by a “port” or cable, if summed in the powered device, will be more than the individual circuits and therefore may exceed the requirements for a limited-power circuit. This might require the use of a fire enclosure and flame retardant materials or the evaluation of performance during single fault and abnormal operation tests.

In summary, according to the NEC, four-pair data communications cabling is permitted to handle up to 400 watts, provided the necessary precautions and powering schemes are used.

TEMPERATURE RISE CONSIDERATIONS

TIA had previously developed a method of testing and comparing heat rise performance in current-carrying category cables for the initial release of TIA TSB 184:2009 in order to provide guidelines for 802.3at standards.



The figure on the left shows the configuration for a 91-cable bundle. The test consists of powering each conductor of this bundle with a test current and measuring the temperature rise of the center cable at a steady-state temperature. By assuming a 45°C maximum ambient temperature and a generalized cable operating rating of 60°C, they allowed for 15 degrees of heat rise for durability and effective use of data cabling. Commercially available cable rated higher than 60°C can naturally withstand higher temperatures and hence provide several key benefits to high-power applications.

In addition to this, the conventional recommendation of PoE systems is that increased power will relate to increased category cabling. For example in 802.3at PoE+ (30 Watts PSE), category 5 cabling is the most basic construction, which will provide sufficient conductivity to run with no heat generation issues, hence it became the minimum requirement. The same recommendation by TIA and the IEEE task force can then be expected with 802.3bt with the specified 600mA/pair max. The reduced heat generation of higher category cables is inferred mostly from the more stringent attenuation requirements of higher category cabling causing cable manufacturers to increase the conductor size. For example, a typical category 5e cable is constructed with 24 AWG conductors, while typical category 6A has 23 AWG conductors. However, now that 1000mA/pair is a real possibility, it will redefine what is acceptable for PoE between 60 watts and 100 watts.

To better demonstrate the differences between these cabling types with the high-current load, we have performed an extensive analysis on the difference in heat generation.

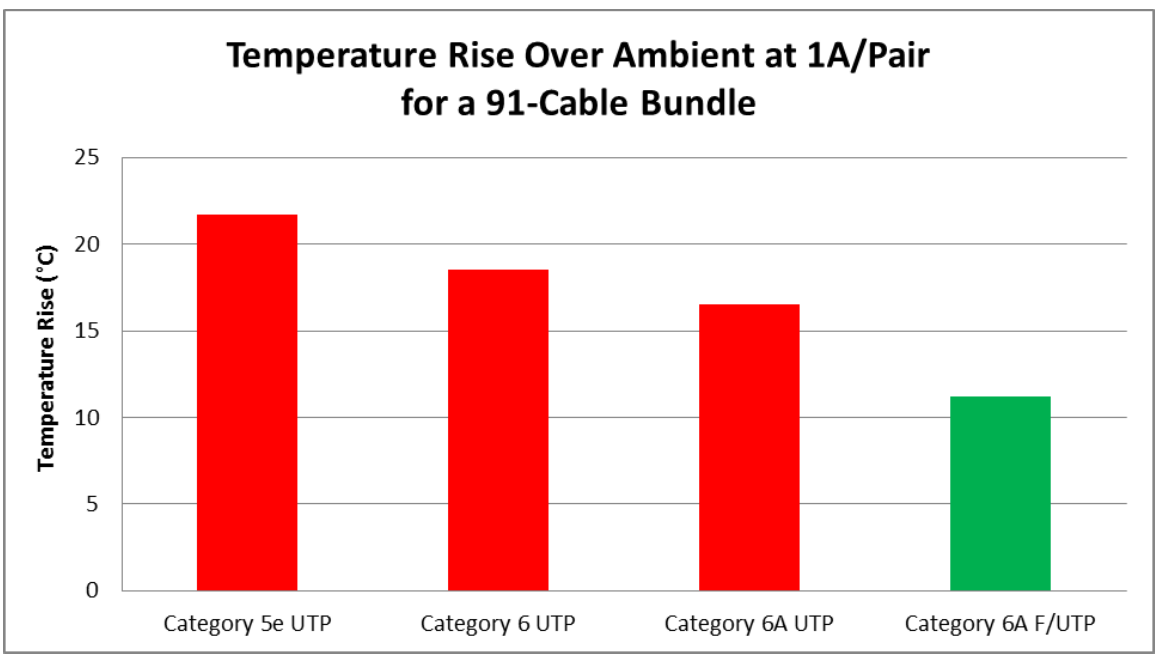


Figure 2: Observed temperature rise over ambient temperature of different category cables in a 91-cable bundle with 1000mA/pair power.

It is quite clear that heat generation becomes a real issue in many of the most common cable constructions installed or available today. However, it is not an ideal assumption to use category designation as a PoE classification rating because the majority of the heat generated from running amperage is due to conductor size or the presence of a shield.

There is an important additional complication to heat generation that has not been discussed: the environment where the cable bundle is located. All the data presented above is in open air, however, in many cases a large cable bundle may be reside beneath a floor, behind walls or enclosed in an insulated space. In the last circumstance, the heat rise figures are significantly worse with numbers as high as 50°C above ambient temperature for the typical worst-case category 5e construction.

Currently, in applications where higher-power usage is expected in excess of 50 watts, yet higher data transmission rates are not required, there are few, if any, options. To appropriately address the increased temperature rise for a reasonable allowed bundle size, one could be confined to using category 6A or category 6A F/UTP. The limiting factor of many devices, especially IP cameras, nurse call systems, building management controls and point-of-sale is power consumption, not data. This places a difficulty on premise designers to justify the use of higher category cabling or the need to pull a power source onto a location.

IMPLICATIONS OF POE REQUIREMENTS TO CABLE DESIGN

Systems that employ higher-power devices require superior performance on insertion loss, heat rise and temperature capabilities. Cable manufacturers are paying attention and have begun to market the PoE characteristics of their category cables. There are even products on the market now that have been specifically designed for PoE, employing larger-gauge conductors for enhanced heat rise and electrical performance.

The benefit of PoE-designed cables can be seen in the chart below, which shows how cable design can impact the amount of heat generated and resulting effect to the ambient environment. As shown in the graph below, standards-compliant category 5e and 6 cables, when powered at 1A/pair in a 91-cable bundle, exceed the 15-degree heat-rise requirement. Cables that employ either a larger gauge size, such as a 22 AWG category 6 construction, or shielding, such as a category 6A product with a discontinous tape, exceed that requirement.

Another strategy for cable manufacturers to handle the increased operating temperatures of these applications is to create cables with higher temperature ratings such as 75°C or 90°C. The added temperature buffer effectively increases the 15-degree temperature rise maximum to 30 degrees and 45 degrees respectively. Notice that this allows for a significantly improved buffer for most applications, which in turn simplifies the building design and cable consideration process.

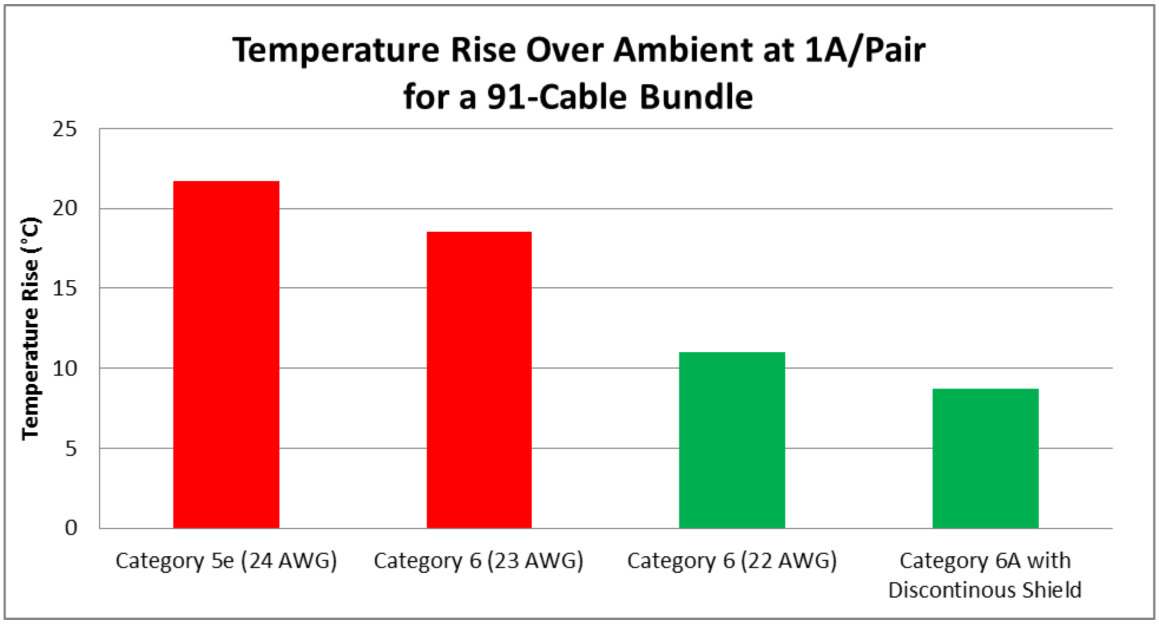


Figure 3: Temperature rise comparison between standard cabling and PoE-enhanced products

IMPLICATIONS TO BUNDLE SIZE

There are real implications to the system designer or contractor who is installing a higher-power PoE system. Because of the heat generated by traditional category 5e and 6 cables, bundle size can be limited, which can add to the complexity and cost of an installation. The chart below compares maximum bundle sizes that will produce less than the 15°C heat-rise requirement; standards-compliant category 5e and 6 cables were compared to a category 6 cable with a larger conductor and a category 6A product with a discontinuous metallic shield.

The analysis illustrates that at even 60 watts, the maximum number of cables that can be bundled together while meeting the 15-degree heat-rise requirement becomes an important factor to consider. At higher wattages, the limitations of standards-compliant cables can become a real limitation to system design. It is important to recognize that this bundle-size limitation applies to any point within the channel. Again, the benefit of PoE-designed cables is clear.

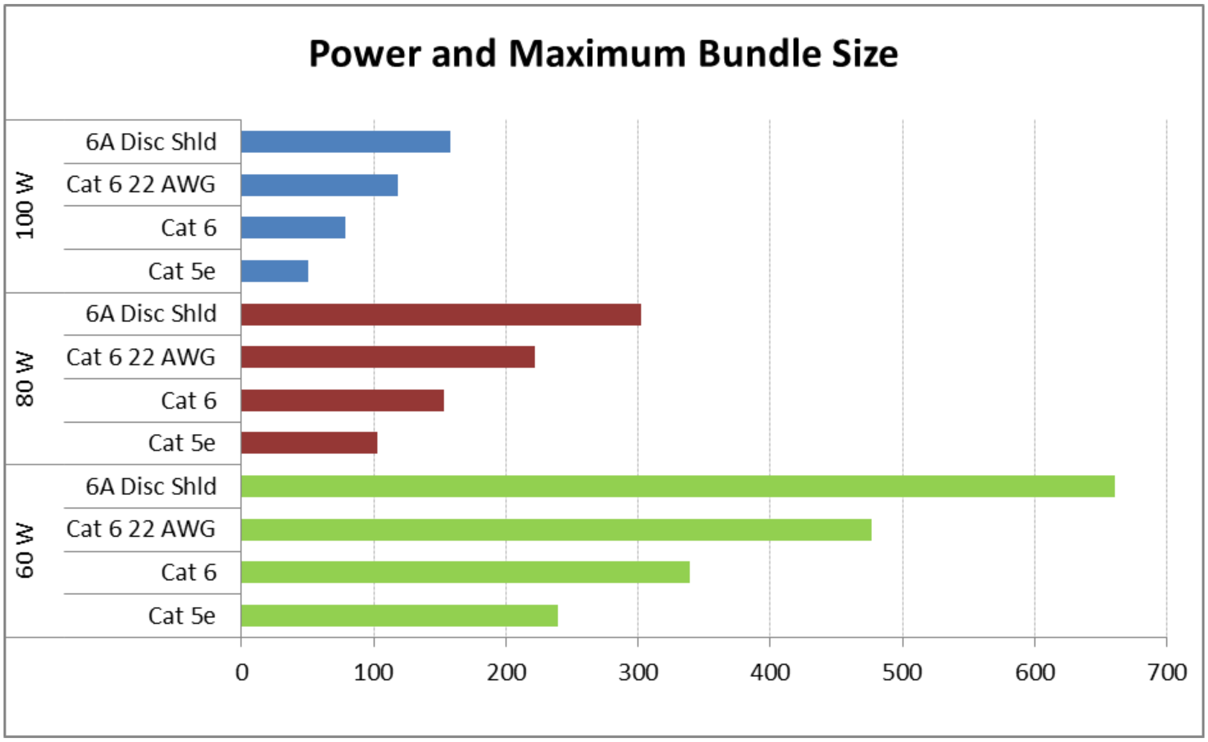


Figure 4: Calculated approximate maximum bundle size that produces less than 15°C heat rise over ambient temperature when using a 60°C rated cable.

ENERGY COST ANALYSIS

There are real benefits to using specially designed PoE cabling with properties such as larger, lower-gauge conductors and higher temperature cable ratings for the majority of PoE applications. Aside from the peace of mind granted from the confidence that the cable will withstand higher-temperature operations as well as lower generated temperatures, energy savings and efficiency are also considerations when deploying a large scale PoE infrastructure.

	Cat 5e (Typical)	Cat 6 (Typical)	Cat 6A (Typical)	22 AWG Cat 6
DC Resistance Per Conductor at 100m	9 Ω	7.5 Ω	6.5 Ω	6 Ω

Table 2: Resistance figures of typical category 5e, category 6, category 6A and 22 AWG category 6

Running 100 devices at 100 watts at a 100-meter distance can translate to significant savings in power simply in resistance losses through the cables alone.

Circuit calculations for a four-pair PoE system can be made multiple different ways depending on the protocol used. One way to calculate power losses across the cable would be to assume two circuits, each having one pair as live and a second pair as neutral. Each circuit resistance would be:

$$\frac{1}{\left(\frac{1}{R}+\frac{1}{R}\right)}+\frac{1}{\left(\frac{1}{R}+\frac{1}{R}\right)}=R$$

Where R is DC resistance per conductor at 100m

Assuming $0.15/KWh, the power loss by driving 100 watts through a cable would be given by:

$$1A^2 \times Circuit\ Resistance \times 2\ Circuits \times 24\ h \times 365\ Days \times \frac{1\ KW}{1000\ W} \times \frac{\$0.15}{kWh} \times 100\ Devices$$

**Four-pair PoE will yield equivalent resistance losses regardless of circuit connection method as long as voltage and power delivered are kept constant and calculations are adjusted accordingly.*

	Cat 5e (Typical)	Cat 6 (Typical)	Cat 6A (Typical)	22 AWG Cat 6
Annual Power Consumption	$2365.2	$1971	$1708.2	$1576.8

Table 3: Annualized cost to power 100 100-watt devices over different cables.

With just 100 devices, the annual energy cost savings between a standards-compliant category 5e cable and a larger-gauge size category 6 cable is estimated at $780. Considering the rapid growth of powered devices and the cost difference of higher-end cables, larger-gauge cables can provide a viable alternative to optimizing infrastructure cost and building energy efficiency.

In addition to direct power-loss savings, reducing heat in temperature-sensitive areas such as data centers can contribute to a significant reduction in power consumption. Using the same parameters as above, the heat generated annually by each cable type is given below.

	Cat 5e (Typical)	Cat 6 (Typical)	Cat 6A (Typical)	22 AWG Cat 6
Annualized energy loss for each 100m cable at 100 W	157.7 kW	131.4 kW	113.9 kW	105.12 kW

Table 4: Annualized energy loss for each 100m cable at 100 W power.

All of the energy loss presented in table 4 is converted into heat energy per energized cable that will have to be accounted for when considering the cooling load of a server room. This is especially important when considering that server rooms could potentially have thousands of these cables converging where temperature is most sensitive.

By assuming three percent improved power usage efficiency for each degree Celsius reduced, we can quantify some significant savings from mitigating the heating of a server room. Taking a case study baseline from Panduit's white paper titled "Impact of Air Containment Systems," we can expect that for a data center with 182 cabinets and parameters specified in that paper to be consuming a total of 4,251,250 kWh. Even a one-degree Celsius drop in the heat generated could translate to an annualized energy savings of $19,130.

POWERING THE NEXT GENERATION OF WIRELESS

There has been much public conversation about the explosive growth in wireless technology in recent years, specifically in that of 802.11ac capable devices. With wave 2 on the very near horizon, the ability to provide 10G speed has become a necessity for future proofing new wireless installs. Although current wireless access points (WAPs) typically draw less than 60 watts of power, it is only a matter of time before the market requires higher-power devices to fulfill ever-growing data needs of the end user. Another likely outcome of growing data needs is more access points, increasing the bandwidth that can be provided to each user; this will subsequently increase the amount of cable required for each installation.

All of these factors point to a category 6A product with enhanced PoE capabilities as the ideal product for 802.11ac WAP applications. Future access points will be more powerful, which will have implications to heat rise and allowable bundle size. An enhanced category 6A PoE product that features a shield will allow for the most flexibility and efficient installations, as well as provide the most security to the end users as they look to future proof their facilities.

CONCLUSION

High-power PoE is an area of much new information and consideration. The proposed IEEE802.11bt will address some of the demand for increased power delivery to the device, but several applications have already extended to 100 watts. Due to the ever-increasing current capacity that is being applied onto Ethernet cabling, many of the previous recommendations and safety issues need to be reevaluated.

This study has shown some of the key areas that are most significantly impacted such as heat generation and insulation degradation in order to highlight the necessary consideration when choosing the right cable for premise wiring.

For applications requiring beyond 60 watts and approaching 100 watts, much benefit can be gained from using cabling designed to handle the increased current capacity such as reduced temperature rise, optimal power delivery efficiency and improved efficiency in operating costs. Furthermore, there is merit from ensuring that a cable will withstand elevated temperatures in order to prevent breakdown of existing installed cabling.

REFERENCES

[1] Content for this section provided by Underwriters Laboratory

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