Workshop Proceedings: Power Over the Ethernet

FINAL PROCEEDINGS BY:
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These are the proceedings of a Workshop on Power Over the Ethernet (PoE). The Workshop was held on 3 October 2017 at the University of New Hampshire InterOperability Lab (UNH-IOL) in Durham, New Hampshire. This topic is of direct interest to multiple organizations and committees responsible for the administration of model codes and standards (e.g., NFPA 70, National Electrical Code®, NFPA 72 Fire Alarm, NFPA 79 Industrial Machinery, NFPA 99 Healthcare, NFPA 730/731 Premises Security, and NFPA 1221 Emergency Services Communication Systems).

The workshop goal was to facilitate a research planning effort for the consideration of concepts involving Power over the Ethernet (PoE), to identify and prioritizes knowledge gaps and recommend next steps and action items in support of the applicable codes and standards. Objectives included: summarizing activity and trends (e.g., common and perceived applications); confirming the definition of PoE and jurisdictional scope of applications; clarification of technology and perceived obstacles (e.g., types of common equipment using PoE, changes to cable constructions, relationship between PoE cable and IOT, etc.); update of impacted stakeholders (e.g., role of stakeholders, etc.); and review of all pertinent supporting information critical to stakeholders (e.g., applicable codes & standards [IEEE, NFPA and others], product safety evaluation, certification, etc.).

The workshop agenda included a review of previous work, on-going relevant work, discussion on data gaps on the topic, and recommendations for effective dissemination and future research. The key takeaways from the workshop re-affirmed the importance of this topic and its potential broad impact, and highlighted certain specific areas that need further attention. This included technical issues such as clarifying terminology, as well as non-technical issues such as the need for training and awareness campaigns. The key summary observations from this summit are the following:

1. **Regulatory Coordination**: define terminology; declare goals and objectives; clarify occupancies and applications; establish key attributes; facilitate enforcement; address products; and document coordination.
2. **Key Technical Issues**: define power versus communication; address intelligent coordinated power; outline risk analysis approaches; address data integrity; and clarify power supplies.
3. **Research and Data**: clarify predictive data analytics; address fundamental baseline issues; and address knowledge gaps.
4. **Training, Education and Awareness**: implement training and education; optimize format delivery; facilitate awareness outreach; and promote stakeholder engagement.

This workshop on PoE is an important step for addressing this issue, but it is only the beginning of a longer journey as we dive into this new era referred to in the mainstream media as the “Internet of Things.” This new era, along with the devices and technologies that support it, such as PoE, are here to stay. It is imperative that the regulatory community rises to address this new sweeping challenge.
Acknowledgements

This workshop has been supported by a generous grant from the NFPA Research Fund, through the National Fire Protection Association.

This workshop summary report has been prepared by Casey Grant and Jason Zhao, at the Fire Protection Research Foundation. The information contained herein is based on the input of multiple professionals and subject-matter-experts. While considerable effort has been taken to accurately document this input, the final interpretation of the information contained herein resides with the report authors. The content, opinions and conclusions contained in this report are solely those of the authors and do not necessarily represent the views of the Fire Protection Research Foundation, NFPA, Technical Panel or Sponsors. The Fire Protection Research Foundation makes no guaranty or warranty as to the accuracy or completeness of any information published herein.

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The Fire Protection Research Foundation plans, manages, and communicates research on a broad range of fire safety issues in collaboration with scientists and laboratories around the world. The Foundation is an affiliate of NFPA.

About the National Fire Protection Association (NFPA)

Founded in 1896, NFPA is a global, nonprofit organization devoted to eliminating death, injury, property and economic loss due to fire, electrical and related hazards. The association delivers information and knowledge through more than 300 consensus codes and standards, research, training, education, outreach and advocacy; and by partnering with others who share an interest in furthering the NFPA mission. All NFPA codes and standards can be viewed online for free. NFPA's membership totals more than 55,000 individuals around the world.

Keywords: Power over the Ethernet (PoE), Ethernet, IEEE, cable, NEC®, NFPA 70, NFPA 72, NFPA 79, NFPA 99, NFPA 730, NFPA 731, NFPA 1221

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1) Background and Introduction

The infrastructure for low powered data (Ethernet) that is regulated by the NEC® and other codes and standards is changing.

Traditionally, the cables used were only operating at very low power levels. Now, this same cable infrastructure is being used to supply power for IP phones, security cameras, lighting, PLC controllers, mass notification, kiosk/annunciation, charging of electronic devices and other applications.

In many installations, these cables are bundled together in large bundles. If high currents are supplied through these bundles, overheating may result. In the past, advances in fire resistant insulation have significantly reduced the number of fires in signaling circuit cables, though the proliferation of new applications with increasing power demand is raising questions on over-heating and fire risk. Adding to the complexity of this situation is the lack of data on perceived hazards such as fire events, to support or deny specific regulatory requirements. This workshop is needed to clarify if this new application will affect the current safety record.

The goal of this workshop is to facilitate a research planning effort for the consideration of concepts involving Power over the Ethernet (PoE), to identify and prioritizes knowledge gaps and recommend next steps and action items in support of the applicable codes and standards.

In support of this goal, the workshop had the following objectives:

- Summarizing activity and trends (e.g., common and perceived applications);
- Confirming the definition of PoE and jurisdictional scope of applications;
- Clarification of technology and perceived obstacles (e.g., types of common equipment using PoE, changes to cable constructions, relationship between PoE cable and IOT, etc.);
- Update of impacted stakeholders (e.g., role of stakeholders, etc.); and
- Review of all pertinent supporting information critical to stakeholders (e.g., applicable codes & standards [IEEE, NFPA and others], product safety evaluation, certification, etc.).
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2) Agenda and Presentation Overview

The agenda for this workshop is illustrated in Table 1: Workshop Agenda. This was structured to provide an overview of previous work, review on-going relevant work, discuss data gaps, reflect on areas for future work, consider recommendations on effective next steps, and discuss other applicable issues. Break-out groups were utilized to maximize participation by all attendees in smaller more engaged groups.

### Table 1 Workshop Agenda

<table>
<thead>
<tr>
<th>TIME</th>
<th>Agenda: Tuesday 3/October 2017</th>
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</thead>
<tbody>
<tr>
<td>8:00 – 8:05am</td>
<td>Call to Order, and Meeting Preliminaries</td>
<td>Casey Grant</td>
</tr>
<tr>
<td>8:05 – 8:15am</td>
<td>Welcoming Remarks</td>
<td>Meeting Hosts</td>
</tr>
<tr>
<td>8:15 – 8:20am</td>
<td>Workshop Objectives &amp; Deliverables</td>
<td>Casey Grant</td>
</tr>
<tr>
<td>8:20 – 9:05am</td>
<td>Overview Presentation: Future of Power over the Ethernet</td>
<td>George Zimmerman</td>
</tr>
<tr>
<td>9:05 – 9:35am</td>
<td>Overview Presentation: Today’s Safety Infrastructure</td>
<td>Don Bliss</td>
</tr>
<tr>
<td>9:35 – 9:50am</td>
<td>Introduction to PoE and PoE Certification Testing at UNH-IOL</td>
<td>Jeff Lapak</td>
</tr>
<tr>
<td>9:50 – 10:50am</td>
<td>Tour of UNH-IOL, PoE showcase, and Morning Break</td>
<td>Panel Members</td>
</tr>
<tr>
<td>10:50 – 11:50am</td>
<td>Stakeholder Panel Discussion: (Invited and Pending)</td>
<td>Donny Cook, Ernie Gallo, Jeff Sargent, Jim Simpson, Wayne Moore</td>
</tr>
<tr>
<td>11:50 am – Noon</td>
<td>Break-Out Group Assignments</td>
<td>Casey Grant</td>
</tr>
<tr>
<td>12:00 – 1:00pm</td>
<td>Networking Lunch</td>
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<tr>
<td>1:00 – 1:45pm</td>
<td>Practical PoE Case Study Issue: Data Collection &amp; Margins of Safety</td>
<td>Chad Jones / Randy Ivans</td>
</tr>
<tr>
<td>1:45 – 3:00pm</td>
<td>Break-Out Group Discussions</td>
<td>All Attendees</td>
</tr>
<tr>
<td>3:00 – 3:15pm</td>
<td>Afternoon Break</td>
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<tr>
<td>3:15 – 4:15pm</td>
<td>Break-Out Group Reports</td>
<td>All Attendees</td>
</tr>
<tr>
<td>4:15 – 4:45pm</td>
<td>Plenary Discussion and Prioritization of Next Steps</td>
<td>All Attendees</td>
</tr>
<tr>
<td>4:45 – 5:00pm</td>
<td>Workshop Closing Remarks and Adjournment</td>
<td>Casey Grant</td>
</tr>
</tbody>
</table>

The overall workshop baseline was established by the following three presentations: first by George Zimmerman summarizing the past, present and potential future of Power over the Ethernet; second by Don Bliss on a regulatory overview of the safety infrastructure; and third by a presentation from Jeff Lapak on the introduction to PoE and PoE Certification Testing at UNH-IOL.

The opening presentations reviewed key fundamentals that were independently known in part by most attendees but not necessarily by all collectively. The slides for all the workshop presentations are included in Annex B. The following is a brief summary of each of these three presentations:

- George Zimmerman clarified the future of PoE with review of certain defined concepts and terms, how the regulatory documents have been attempting to address this topic; and emerging issues like single pair and Intelligent Coordinated Power (ICP) & Energy Management Systems.
- Don Bliss provided a high level overview of the regulatory infrastructure, and the involved process of revising, maintaining and legislative adoption of modes code and supporting standards, along with the critical needs of the enforcement infrastructure.
- Jeff Lapak outlined an overview of certification testing for PoE, against a backdrop of the operational details of the University of New Hampshire’s InterOperability Laboratory.

The slides used by these speakers provide additional detail. One example of helpful overview information is the categorization of the PoE Types and Classes handled by the InterOperability Laboratory, and this is
illustrated in Figure 1, Interoperable PoE Types and Classes. This is shared here as a case study approach for providing clarity and categorizing basic PoE.

![Figure 1 Interoperable PoE Types and Classes]

A panel discussion was held after attendees had a tour through the University of New Hampshire’s InterOperability Laboratory to witness actual PoE applications, testing and research. After the tour, five subject matter experts representing the broad spectrum of stakeholder interests held a panel discussion on the current development and regulations of PoE equipment. This was composed of the following: electrical inspector (Donny Cook), NEC task group chair on PoE (Ernie Gallo), legislative facilitator (Jeff Sargent), premises security (Jim Simpson), and fire alarm (Wayne Moore).

The panel included a broad cross-section of representation, and they clarified specific issues and concerns relating to enforcement, regulatory adoption, processing of code revisions for emerging technologies, end-user interests, and specific applications like fire alarm and premises security. This stimulated dialogue with all workshop attendees and highlighted certain dimensions of this topic area. Multiple points were discussed, and examples include (but not limited to) the following:

- concepts of retrofit and renovation don’t easily apply since PoE is typically considered ever-changing and on-going;
- enforcement approaches are critical and need clarification;
- data itself is a new commodity and requires special attention to maintain its safe use (e.g., data used for critical tasks like surgery require high levels of integrity); and
- training and education (e.g., IT departments that have traditionally had oversight of a facilities PoE and will need new or different training);

After the Panel discussion, a joint back-to-back presentation session was provided by Chad Jones of Cisco and Randy Ivans of UL, presenting on the topics of Data Collection and Margins of Safety for PoE. Through separate independent presentations these both addressed the fundamental issue of bundling of cables with higher power loads, and perceived hazard concerns based on metrics such as factors of safety. Both described the science behind this issue and clarified empirical testing and case study situations to support the science. This brought clear focus on attempts to quantify bundling of cables with increased power loads that can potentially support or be translated into certain regulatory requirements.

All attendees then broke into four different groups discussing the key issues that needed to be addressed. The four groups each did a presentation based on their discussion and finally, Casey Grant facilitated a
final discussion on areas/data for future research and dissemination. The workshop participants are summarized in Annex A. Figure 2 provides an illustration of the workshop presentations.

Figure 2 Workshop Presentations While In Session
3) Break-Out Group Discussions

Following introductory remarks and baseline presentations up through the lunch break, breakout group discussions were conducted to clarify the collective consensus perspective on a series of key questions. The questions are summarized in Table 2: Break-Out Group Questions. These questions were distinctly separated into baseline issues, fundamental issues, topical issues, and general issues. Of these, the topical issues were intended to be more focused on tangible on-going sub-topics areas of high interest, and this exercise was intended to surface other issues not already addressed by the questions in Table 2.

### Table 2 Break-Out Group Questions

<table>
<thead>
<tr>
<th>Break-Out Group Questions</th>
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<tbody>
<tr>
<td><strong>1) BASELINE ISSUES (20 minutes)</strong></td>
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<tr>
<td>a) <strong>Terminology</strong></td>
</tr>
<tr>
<td>b) <strong>Define Key Issues</strong></td>
</tr>
<tr>
<td>c) <strong>Data &amp; Data Analytics</strong></td>
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<tr>
<td>d) <strong>Stakeholders</strong></td>
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<tr>
<td>e) <strong>Other</strong></td>
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<tr>
<td><strong>2) FUNDAMENTAL ISSUES (20 minutes)</strong></td>
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<tr>
<td>a) <strong>Hazard</strong></td>
</tr>
<tr>
<td>b) <strong>Applications &amp; Occupancies</strong></td>
</tr>
<tr>
<td>c) <strong>Other Fundamental Issues</strong></td>
</tr>
<tr>
<td><strong>3) TOPICAL ISSUES (20 minutes)</strong></td>
</tr>
<tr>
<td>a) <strong>Managed Loading (aka, dynamic loading or smart loading)</strong></td>
</tr>
<tr>
<td>b) <strong>Factors of Safety</strong></td>
</tr>
<tr>
<td>c) <strong>Scalability of Applications</strong></td>
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<tr>
<td>d) <strong>Product Issues</strong></td>
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<tr>
<td>e) <strong>Other Topics</strong></td>
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<tr>
<td><strong>4) GENERAL ISSUES (15 minutes)</strong></td>
</tr>
<tr>
<td>a) <strong>Research Gaps</strong></td>
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<tr>
<td>b) <strong>Future Trends</strong></td>
</tr>
<tr>
<td>c) <strong>Other Issues</strong></td>
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</tbody>
</table>
The break-out groups were evenly balanced with a diverse mix of attendees. They were given a neutral identifier in no order of priority as follows: Group 1; Group 2; Group 3; and Group 4. They collectively reported back during the plenary session as summarized in Table 3: Individual Break-Out Group Results. This summarizes the raw output from each of the four break-out groups (with editing for clarity and consistency). It’s noted that not all groups responded to each question.

Table 3 Individual Break-Out Group Results

<table>
<thead>
<tr>
<th>1) BASELINE ISSUES</th>
<th>BREAK-OUT GROUP QUESTIONS</th>
</tr>
</thead>
</table>
| a) **Terminology.** What key terms need standardized universal definitions (e.g., PoE, wire, cable, managed loading, etc.)? | **GROUP 1**  
• Define PoE (i.e., what do we call PoE?).  
• Clarify power over LAN cable or power over communication cable.  
**GROUP 2**  
• Transmission of data and power  
• The basic definition of a “bundle”  
• Focus on using “Current” and not “Power”  
• Clarify “communication power”  
• Clarify “PoE Power” not used for communications  
• Clarify “workmanlike manner”  
• Define PoE in terms of universally understanding “safe PoE”  
**GROUP 3**  
• Wire vs Cable -  
• Bundle -  
• PoE -  
• Power -  
• Low Voltage, Limited Energy might be better  
• How to differentiate class/types between specification -maybe have them reference each other  
• ICP (Intelligent Coordinated Power)  
• COPS (Critical Operations Power System)  
**GROUP 4**  
• What is power? (i.e. lighting, low voltage, Class 2 power, etc.)  
• What is PoE? (do we need to define it and use it)  
• Bundle? What constitutes a bundle? (i.e. cable laying in tray?)  

b) **Define Key Issues.** Identify, define and prioritize the critical baseline issues, such as: (i) levels of integrity (e.g., COPS Critical Operations Power Supply, fire alarm, security, egress, lighting, etc.); (ii) interruption and surge hazards (for equipment); factors of safety; and other topical issues.  
**GROUP 1**  
• POE is a technology  
• Code definition of a communication circuit vs class II circuit
• Different requirements on wires that do the same thing. Consider the physics of the wire as the limiting factor. The same regulatory requirements should apply regardless of the application the wire is used (e.g., communications versus video surveillance).
• Consider specifications for all cables, and not only network cables.
• Address pairing of cables (i.e., single pair cabling, double, quadruple).
• Address mixed cables.
• Clarify lack of conduit filling requirements in NEC chapter 8
• Address all aspects of inspections, both before and after equipment is installed.
• Consider new labeling requirements for switches.
• Address a data supported exception for class 4 PoE.
• Coordinate listing requirements that transfer liability and assure continued safety.
• Coordinate the designer’s cable plan with the specifications used by the contractors for the installation.
• Declare how the PoE circuits are going to be used, for the inspectors and others.
• Clearly define cable use, with different colors for different uses.
• Define realistic worst-case scenarios.

GROUP 2
• Powering for communications
• Transmission for power only
• PoE for fire safety applications (including fire alarms)

GROUP 3
• Secondary Power Source
  • Define priorities like how NFPA 72 handles signals
  • e.g., UPS (Uninterruptible Power Supply)
• Define functionality
• Shared networks
• Education and training for all
• Define system robustness
• Clarify true PoE versus simply running power over an Ethernet cable
  • Focused only on chapter 8 for communication cable that use power, that is dangerous
  • E.g., cable type versus application
• Resources for inspection and third-party verification
• Re-inspection

GROUP 4
• Confusion of PoE Class & NEC Class
• Define power by use or by itself? Technology vs. function delineation
• PoE & non-PoE – What is it? Or what isn’t it? What defines it?
• What is a communications device or circuit?
• Levels of integrity for functionality
• Is 60 v High or low voltage?
• Is PoE a fire hazard or more an issue for degradation of information or integrity of cable?
• 50v vs. 60v – shock hazard, etc.
c) **Data & Data Analytics.** Identify and prioritize key data & data analytic needed to impact policy and related activities. Identify and describe the barriers and obstacles for addressing data in support of safety concerns, including non-technical (e.g., legal, privacy, labor, security, etc.)

**GROUP 2**
- Clarify relevant data points and elements (e.g., 400 mA level versus 350mA or 450mA).
- Address smaller bundle cables.
- Provide support for local inspectors.
- Clarify role and use of third party.
- Consider the use of a checklist or punch list for the third party support and enforcement

**GROUP 3**
- Clarify data needs
- Clarify occupancies
- Prospectively collect data
  - e.g., surge and interruption
  - e.g., chapter 7 versus chapter 8
- Centralized national data collection, to influence policy

d) **Stakeholders.** Which stakeholders are needed to address this topic? Who is missing or under-represented?

**GROUP 1**
- Insurance
- NFPA79 on industrial machinery

**GROUP 2**
- Owner (of facility, building, application, etc.)
- Supplier of equipment or system
- On-site end-user representative (e.g., office manager or facilities representative)
- Inspectors
- Installers
- Community (i.e., broad consumer interests)
- Communication utilities

**GROUP 3**
- NFPA 1221 representatives (911 centers)
- End-users (e.g., Am. Soc. for Healthcare Engineering, Assoc. of Physical Plant Admin, etc.)
- Building code users

**GROUP 4**
- Inspectors
- Installers
- Manufacturing
- Designers
- Contractors
- Owners/End Users (underrepresented)
- Research & Testing
- Insurers
### 2) **FUNDAMENTAL ISSUES**

#### a) **Hazards**
Summarize and prioritize the key electrical hazards (e.g., shock, arc-flash, surge, interruption, etc.) and key fire related hazards (fire ignition, fuel load, flame spread, products of combustion, etc.).

<table>
<thead>
<tr>
<th>GROUP 1</th>
<th></th>
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<tbody>
<tr>
<td>• Smoke propagation</td>
<td>• Toxicity</td>
<td>• Data integrity</td>
<td>• Impact on business continuity</td>
</tr>
<tr>
<td>• Shock hazard</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>GROUP 2</th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>• Use of LP (limited power) is not all you need</td>
<td>• Shock hazard from non-approved devices, including plugging and unplugging</td>
<td>• Surge</td>
<td>• Business, Communication and data interruption</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GROUP 3</th>
<th></th>
<th></th>
<th></th>
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<tbody>
<tr>
<td>• On-going ITM: Inspection Testing &amp; Maintenance (e.g., fire alarm maintenance)</td>
<td>• Equipment plugging/unplugging (e.g., cord removal spark concerns)</td>
<td>• Heating/Overheating</td>
<td>• Existing cabling, and when to get permits</td>
</tr>
<tr>
<td>• Cyber security issues</td>
<td>• Interoperability (and compatibility), including with counterfeit equipment and devices.</td>
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</table>

<table>
<thead>
<tr>
<th>GROUP 4</th>
<th></th>
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<tbody>
<tr>
<td>• Is PoE a fire hazard or more an issue for degradation of information or integrity of cable?</td>
<td>• 50v vs. 60v – shock hazard, etc. (some codes call out 50, some 60)</td>
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</table>

#### b) **Applications & Occupancies**
Do regulatory approaches need to be occupancy specific (e.g., similar to NFPA 101)? How should occupancies be sub-divided? How should critical activities like COPS Critical Operations Power System, fire alarm, healthcare and premises security be handled?

<table>
<thead>
<tr>
<th>GROUP 1</th>
<th></th>
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<tbody>
<tr>
<td>• Coordinate data and power in the regulatory codes</td>
<td>• Address circuit integrity</td>
<td>• Address critical systems</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>GROUP 2</th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>• Occupancy specific is important (e.g., Hospital)</td>
<td>• Address and define use of PoE in applicable codes and standards</td>
<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>GROUP 3</th>
<th></th>
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<tbody>
<tr>
<td>• Should be based on risk analysis</td>
<td>• Should be based on applications, and not occupancies (e.g., fire alarms, patient monitoring, surgical suites, etc.)</td>
<td>• Need clear sharp definitions of applications and occupancies</td>
<td>• Challenged by changing physical environment (i.e., use of a building)</td>
</tr>
<tr>
<td>• Clarify the documentation of NEC structure for communications (signaling over power lines)</td>
<td>• Consider residential as a special case vs. other occupancies</td>
<td></td>
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</tr>
</tbody>
</table>
GROUP 4

- Should it be occupancy based vs. PoE presence in the building and how it is installed?
- Installation practice more important than occupancy
- Is augmentation needed in PoE distribution in life safety applications
- Who is appropriately trained for installing a life safety system on PoE? (Team approach – NFPA 72 Class N)
  - Life Safety Issues
  - Priority of Service
  - Ability to hack system

c) **Other Fundamental Issues.** Are there other fundamental issues not mentioned above that should be addressed?

GROUP 2

- Coordinate impact in codes and standards (i.e., don’t solve an issue in one standard and create a problem in another)
- Survivability
- Redundancy
- Cybersecurity
- Reliability
- The needs of the enforcers (i.e., the AHJs: authorities having jurisdiction)
- Listing of products, devices, systems, etc.
- Realistic, informative and relevant punch lists for installers, Inspectors and others

GROUP 4

- Training!!

3) **TOPICAL ISSUES**

a) **Managed Loading (aka, dynamic loading or smart loading).** What are the primary obstacles for the safe use of managed loading? Clarify the necessary safeguards (e.g., integrity/protection/etc.).

GROUP 1

- Address managed loading in the code.
- When systems are wired, make sure they are loaded for occupant safety (critical data needed). Require system controllers to make sure every wire isn’t at maximum load all the time.

GROUP 2

- Expand on the limited information to support a universal understanding
- Clarify operations for better management
- Address the use of AIM (automatic infrastructure management) to improve loading
- Recognize the gray area beyond issues focused only on safety

GROUP 3

- ICP – Intelligent coordinated power
  - Can it be allowed for in the code to expand capacity?
  - Assuming yes, where does it belong, Article 725 or 800?
  - Need two tables – one for ICP and one for non-ICP based
  - Consider a new Article to address ICP (to also enable reference by other codes)
- Need to clarify and address enforcement concerns with ICP
- Need to comprehensively define ICP
GROUP 4

- Can equipment monitor and control distribution to ensure safety?

b) **Factors of Safety.** What are the key elements and characteristics that require factors of safety? Clarify what is presently used (if known), and what is needed.

GROUP 1

- Avoid cable loading controlled by software.
- Provide failsafe backups and reliable hardware.
- Provide a class II back up.
- Coordinate loading as allowed by code.
- Clarify code requirements for monitoring.

GROUP 2

- Clarify the relationship between safety and performance, which now is not clear.

GROUP 3

- Depends on criticality of the application, as defined by a risk analysis.
- Quantify the factors of safety for existing NEC requirements.
- Re-examine and confirm previous assumptions for existing factors of safety.

GROUP 4

- Energy Management vs. all current all the time
- Prioritization (emergency devices) – (Keyed connectors, tool access, application)

c) **Scalability of Applications.** What are the barriers for the safe use of plug-and-play approaches that can substantially increase the needs of the supporting infrastructure (e.g., power supplies, etc.)?

GROUP 1

- Future flexibility of installations is a lot easier with PoE than other approaches

GROUP 2

- The scale of power can be large.
- Clarify which PoE injector should be used when addressing scaling
- Use of multiport and multi-span approaches is a challenge
- Clarify how to handle multi-cable installations

GROUP 3

- Use of existing installations
- Clarify boundaries
- Address ICP: Intelligent coordinated power
- Clarify the limits of plug and play solution, through the product standards

GROUP 4

- Awareness of what to look for to trigger a check

d) **Product Issues.** Identify and prioritize key product issues and concerns (e.g., certification, aftermarket, counterfeit, etc.)

GROUP 1

- Clarify how to maintain priority when on a shared network
- Address temporary interference with safety systems (e.g., viral videos crashing a fire alarm system).
- Address RF (radio frequency) interference, causing integrity and security concerns.
- Address external influences (e.g., space, weather).
GROUP 2
- Coordinate voluntary model product standards (e.g., IEEE) with mandatory adopted codes.
- Address non-compliant equipment
- Consider listing performance standards
- Include reference to IEEE standards in all applicable NFPA documents (e.g., NFPA 72 and 730)

GROUP 3
- Lacking a clear definition of PoE, leading to fake and/or false claims.
- Counterfeit products (i.e., from the cyber marketplace).
- Providing listed products versus self-certification.
- Listing for the intended purpose, possibly as a complete system (e.g., a listed PoE switch, though not as part of a fire alarm system that might have additional requirements).
- Address listing for software, and/or other methods to assure software integrity.

GROUP 4
- Self-Certification and AHJ approval – may be a barrier to acceptance

**e) Other Topics.** Are there other key topical issues not mentioned above that should be addressed?

GROUP 1
- Continue to promote the technology advisory and coordination process

GROUP 2
- Continuing coordination among impacted stakeholders

**4) GENERAL ISSUES**

**a) Research Gaps:** What research is currently needed? What is the priority for this research?

GROUP 1
- Identify and address the gaps in the regulatory landscape (i.e., codes and standards).
- Clarify data on bundles (e.g., single pair cabling versus data on 25 pair cabling).
- Address inter-document technical coordination

GROUP 2
- Need modeling and theories, in addition to measurements and testing
- Address and clarify the regulatory environment (i.e., how the code is administrated)
- Provide effective training/education for installers and inspectors
- Establish tools for design, installation, and inspection (e.g., checklist for implementation)

GROUP 3
- Data to define future trends, based an on-going data collection plan
  - Clarify the underlying data architecture (e.g., loads, failures, etc.).
  - Address data from devices versus data on devices.
  - Identify the data that should be captured, as well as its intended use (e.g., fire alarm operation for policy and code changes).
- Interoperability and compatibility of devices and systems.

GROUP 4
- Traditional builds vs. future PoE builds and how does it affect branch circuits and PoE to successfully replace life safety systems?
- How to control/recognize “Non PoE”?
- Survey of “Power & Data” methods applications and characteristics.
b) Future Trends: With continually evolving technologies and materials, what other issues should be considered, now and in the future?

GROUP 1
- Consider PoE desktops applications (e.g., computer running the fire alarm system).

GROUP 2
- Define the emerging technology
  - Single pair implementation [100 meters reach with 1GB, 50 watts (2 wires)]
  - Connector resistance
  - Internet of Things infrastructure (thermostats, sensors)
  - Back-up power
  - Transmit thermal performance
  - API (Application Programming Interface) switch

GROUP 3
- Use of more power (e.g., 200 watts).
- Coordination of all applicable standards (e.g., IEEE standards)
- Proliferation of the “Internet of Things” (or whatever the preference is to call the trend of all things to ultimately communicate).

GROUP 4
- How to deal with technology moving faster than codes?
- Traditional builds vs. future DC Distribution builds and how does it affect branch circuits and DC Distribution to successfully replace life safety systems?
- Survey of “Power & Data” methods applications and characteristics.
  - What are the hazards associated with these? Prioritize, classify and what now is needed?

Other Issues? Are there any other issues not addressed elsewhere? For PoE safety, are there any declarative statements on this topic that are important and should be stated?

GROUP 1
- Involve other stakeholders, such as NFPA 79 representative and insurance.
- Establish an advisory council to coordinate technical requirements between the codes and standards.

GROUP 2
- Consider the following priority topics:
  - Define and clarify communication/data/power versus just power
  - Implement Training and education
  - Conduct research (modeling and theories)
  - Clarify virtues of these emerging technologies like PoE
  - Address the needs of the entire ecosystem of stakeholders (e.g., designers, developers, vendors, installers, inspectors, end-users, etc.).
balanced mix of subject matter expertise in each group, so that the groups could provide balanced discussion.

Each group appointed a lead facilitator, a recorder and a timekeeper. Following the independent discussions of each group, each lead facilitator reported out their results in a short presentation during a plenary session. This revealed multiple consistent issues. A summary of the consolidated results for each question is shown in Table 4: Consolidated Break-Out Group Results. This provides an important distilled deliverable from this workshop.

**Table 4 Consolidated Break-Out Group Results**

<table>
<thead>
<tr>
<th>CONSOLIDATED BREAK-OUT GROUP RESULTS</th>
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</table>

1) **BASELINE ISSUES**

i) **Terminology.** What key terms need standardized universal definitions (e.g., PoE, wire, cable, managed loading, etc.)?

- Define PoE: Power over the Ethernet
  - Need universal detailed understanding of the concept
  - Clarify Transmission of data and power
  - Clarify “PoE Power” not used for communications, and used for “communication power”
- Define key mainstream concepts lacking universal definitions, such as: wire, cable, bundle, workmanlike manner
- Define ICP: Intelligent Coordinated Power
- Define COPS: Critical Operations Power System, and other important power systems

b) **Define Key Issues.** Identify, define and prioritize the critical baseline issues, such as: (i) levels of integrity (e.g., COPS Critical Operations Power System, fire alarm, security, egress, lighting, etc.); (ii) interruption and surge hazards (for equipment); factors of safety; and other topical issues.

- Training, Education and Awareness
  - Provide training for all.
  - Recognize POE as a technology.
  - Clarify the advantages and disadvantages of PoE.
- Design Issues - General
  - Clarify powering for communications
  - Clarify transmission for power only
  - Establish fundamental parameters, such as functionality, system robustness, shared networks,
  - Define PoE use for fire safety applications (e.g., fire alarms)
  - Address secondary power supplies
- Design Issues - Wire and Cable
  - Consider specifications for all cables, and not only network cables.
  - Consider the physics of the wire as the limiting factor, with the same regulatory requirements regardless of the application the wire is used (e.g., communications versus video surveillance).
  - Address pairing of cables (i.e. single pair cabling, double, quadruple).
• Address mixed cable types and applications (e.g., LP Limited Power and non-LP, or some data only, or some data and power combination).

• Inspection, Enforcement and Commissioning
  o Address all aspects of inspections, both before and after equipment is installed.
  o Define realistic worst-case scenarios.
  o Declare how the PoE circuit are going to be used, for the inspectors and others.
  o Coordinate the designer’s cable plan with contractor’s specifications.
  o Clearly define cable use, with different colors for different uses.
  o Resources for inspection and third-party verification
  o Re-inspection

• Product Issues
  o Consider new labeling requirements for switches.
  o Coordinate listing requirements that transfer liability and assure continued safety.

  c) Data & Data Analytics. Identify and prioritize key data & data analytic needed to impact policy and related activities. Identify and describe the barriers and obstacles for addressing data in support of safety concerns, including non-technical (e.g., legal, privacy, labor, security, etc.)

  • Identify and clarify data needs
  • Prospectively collect data
    o Address surge and interruption
    o Clarify relevant data points and elements (e.g., 400 mA level vs. 350mA or 450mA).
    o NEC chapter 7 applications versus chapter 8
    o Clarify occupancies and applications.
    o Address specific bundles of cables.
    o Provide support for local inspectors.
    o Clarify role and use of third party.
  • Establish a centralized national data collection, to influence policy

d) Stakeholders. Which stakeholders are needed to address this topic? Who is missing or under-represented?

  • Communication utilities
  • Consumer and community representation (i.e., broad consumer interests)
  • Contractors and installers
  • Designers (of applications and installations)
  • Equipment and system suppliers (i.e., manufacturers)
  • Inspectors, Enforcers and AHJs
  • Insurers
  • NFPA 79 representatives (e.g., industrial machinery)
  • NFPA 1221 representatives (e.g., 911 centers)
  • Research and testing
  • Users and Owners (including on-site facility representatives)

e) Other. Are there other baseline issues not mentioned above that should be addressed?

  • Consider the use of a checklist or punch list to facilitate third-party support and enforcement.
2) **FUNDAMENTAL ISSUES**

a) **Hazards.** Summarize and prioritize the key electrical hazards (e.g., shock, arc-flash, surge, interruption, etc.) and key fire related hazards (fire ignition, fuel load, flame spread, products of combustion, etc.).

- **Fire hazards**
  - Smoke propagation and toxicity
  - Fire ignition
    - Heating or overheating
    - Equipment plugging/unplugging (e.g., cord removal spark concerns)
  - Fuel load (e.g., existing cable bundles)
- **Electrical hazards**
  - Shock hazard (e.g., from non-approved devices)
  - Surge and interruption
- **Data hazards**
  - Data integrity
  - Cyber security issues
  - Interoperability (and compatibility)
- **Other concerns**
  - Business, Communication and data interruption (i.e., business continuity)
  - On-going ITM: Inspection Testing & Maintenance (e.g., fire alarm maintenance)
  - Existing cabling

b) **Applications & Occupancies.** Do regulatory approaches need to be occupancy specific (e.g., similar to NFPA 101)? How should occupancies be sub-divided? How should critical activities like COPS, fire alarm and premises security be handled?

- **Regulatory issues**
  - Clarify the documentation of regulatory structure (i.e., NEC) for communications (e.g., signaling over power lines)
  - Coordinate data and power in the regulatory codes
  - Should be based on risk analysis
  - Address and define use of PoE in applicable codes and standards
- **Applications versus occupancies**
  - Need clear sharp definitions of applications and occupancies
  - Establishing clear occupancies is important (e.g., Hospital)
  - Should be based on applications, and not occupancies (e.g., fire alarms, patient monitoring, surgical suites, etc.)
  - Consider residential as a special case versus other occupancies
- **Key concerns**
  - Address circuit integrity
  - Address critical systems
  - Challenged by changing physical environment (i.e., use of a building)
  - Installation practice more important than occupancy
  - Clarify training for installing a life safety system based on PoE to assure integrity (based on life safety issues, priority of service, ability to disrupt or hack, etc.)

c) **Other Fundamental Issues.** Are there other fundamental issues not mentioned above that should be addressed?
• Training
  o Support the needs of enforcers (i.e., AHJs: authorities having jurisdiction)
  o Provide realistic, informative and relevant punch lists for installers, Inspectors and others
• Regulatory coordination
  o Coordinate impact in codes and standards
  o Don’t solve an issue in one standard and create a problem in another)
• Product issues
  o Clarify essential product and system performance characteristics (e.g., survivability, redundancy, cybersecurity, reliability, etc.).
  o Address “listing” of products, devices, systems, etc.

3) TOPICAL ISSUES

a) Managed Loading (aka, dynamic loading or smart loading). What are the primary obstacles for the safe use of managed loading? Clarify the necessary safeguards (e.g., integrity / protection / etc.).
  • Define ICP (Intelligent coordinated power), comprehensively and universally
    o Identify and summarize safety concerns with ICP.
    o Clarify equipment monitoring and control to ensure safety.
    o Expand on the limited information to support a universal understanding
    o Clarify operations for better management
  • Address ICP regulatory requirements
    o Address the use of AIM (automatic infrastructure management) to control loading
    o Coordinate existing requirements, such as NEC Article 725 or 800
    o Consider a new Article to address ICP (to also enable reference by other codes)
    o Consider multiple tables (e.g., one for ICP and one for non-ICP based systems)
    o Require system controllers to assure every wire doesn’t exceed maximum load.
  • Clarify and address enforcement concerns with ICP

b) Factors of Safety. What are the key elements and characteristics that require factors of safety? Clarify what is presently used (if known), and what is needed.
  • Key parameters
    o Clarify the relationship between safety and performance, which now is not clear.
    o Avoid cable loading controlled by software.
    o Provide fail safe backups and reliable hardware (e.g., provide a class II back up.
    o Clarify code requirements for monitoring.
    o Energy Management vs. all current all the time
  • Implement a risk analysis to clarify the criticality of applications.
  • Prioritize emergency and safety devices (e.g., keyed connectors, tool access, application)
  • Existing factors of safety
    o Quantify factors of safety for existing NEC requirements.
    o Re-examine and confirm previous assumptions for existing factors of safety

b) Scalability of Applications. What are the barriers for the safe use of plug-and-play approaches that can substantially increase the needs of the supporting infrastructure (e.g., power supplies, etc.)?
• General issues
o Define boundaries to clarify system scalability
o Clarify the limits of plug and play solution, through the product standards
o The scale of power can be large.
o Future flexibility of installations is a lot easier with PoE than other approaches

- Specific issues
  o Clarify which PoE injector should be used when addressing scaling
  o Use of multiport and multi-span approaches is a challenge
  o Clarify how to handle multi-cable installations

- Other issues
  o Address ICP: Intelligent coordinated power
  o Address existing installations and infrastructure

### d) Product Issues

Identify and prioritize key product issues and concerns (e.g., certification, aftermarket, counterfeit, etc.)

- Regulatory issues
  o Coordinate voluntary model product standards (e.g., IEEE) with mandatory adopted codes.
  o Support performance standards to enable “listed” equipment
  o Include reference to IEEE standards in all applicable NFPA documents (e.g., NFPA 72 and 730)

- Technical concerns
  o Clarify how to maintain priority when on a shared network
  o Address temporary interference with safety systems (e.g., viral videos crashing a fire alarm system).
  o Address RF (radio frequency) interference, causing integrity and security concerns.
  o Address external influences (e.g., space, weather).

- Marketplace concerns and enforcement
  o Address non-compliant equipment
  o Lack of a clear definition of PoE leads to fake and/or false claims.
  o Counterfeit products (i.e., from the cyber marketplace).
  o Providing “listed” products versus self-certification (i.e., self-certification may be a barrier to AHJ acceptance)
  o “List” products for the intended purpose, possibly as a complete system (e.g., a listed PoE switch may need special processing with a fire alarm system).
  o Address listing for software, and/or other methods to assure software integrity.

### e) Other Topics

Are there other key topical issues not mentioned above that should be addressed?

- Promote the overall technology advisory and coordination process
- Facilitate networking and dialogue among impacted stakeholders

### 4) GENERAL ISSUES

a) **Research Gaps:**  What research is currently needed?  What is the priority for this research?

- Regulatory landscape
  o Identify and address the gaps in the regulatory landscape (i.e., codes and standards).
  o Address inter-document technical coordination
Technical issues
- Clarify impact of PoE on existing infrastructure
  - Address interoperability and compatibility of devices and systems.
  - Bundles (e.g., single pair cabling versus data on 25 pair cabling).
  - Traditional builds vs. future PoE builds (e.g., branch circuits)
- Address modeling and theories, in addition to measurements and testing
- Address methods to recognize and control “Non PoE”.

Data and data analytics
- Define future trends, based on an on-going data collection plan
- Clarify the underlying data architecture (e.g. loads, failures, etc.).
- Define and prioritize “power & data” methods applications and characteristics.
- Address data from devices versus data on devices.
- Identify the data that should be captured, as well as its intended use (e.g., fire alarm operation for policy and code changes).

Training and Education
- Provide effective training/education for installers and inspectors
- Establish tools for design, installation, and inspection (e.g., checklist for implementation)

b) Future Trends: With continually evolving technologies and materials, what other issues should be considered, now and in the future?

General issues
- Increase of sensors and need to communicate, based on the proliferation of the “Internet of Things”.
- Need for data and data analytics to clarify trends
- Use of more power (e.g., 200 watts).
- Consider PoE desktops applications (e.g., computer running the fire alarm system).
- Transition of the existing infrastructure versus new applications.
- DC Distribution (i.e., affect branch circuits, etc.).

Emerging technologies
- Conductors (e.g., single pair implementation versus multi-pair)
- Proliferation of the Internet of Things infrastructure (thermostats, sensors)
- Backup power supplies
- Monitoring and coordination of thermal performance
- Connector resistance

Regulatory issues
- Coordination of all applicable standards (e.g., IEEE standards)
- Address technology moving faster than codes?
- Proliferation of the “Internet of Things”.

c) Other Issues? Are there any other issues not addressed elsewhere? For PoE safety, are there any declarative statements on this topic that are important and should be stated?

Regulatory Coordination: Establish an advisory council to coordinate technical requirements between the codes and standards of all involved organizations.

Power and Communication Requirements: Define and clarify communication/data/power versus just power
- Research: Conduct research in support of modeling and establishing theoretical fundaments;
- Training and Education: Implement training and education, and clarify the virtues of emerging technologies like PoE.
- Stakeholders: Address the needs of the entire ecosystem of stakeholders (e.g., designers, developers, vendors, installers, inspectors, end-users, etc.).
- Networking: Promote and facilitate dialogue and networking, and involve all impacted stakeholders (including others such as insurance, NPFA 79 rep, etc).

At the conclusion of the break-out group sessions each group facilitator presented their groups findings. This was followed by a general discussion of issues by all workshop participants. The open discussion revealed multiple consistencies between the four groups, and these are captured and reflected on Table 4: Consolidated Break-Out Group Results. Various other details were mentioned during this discussion. An example was performance attributes, and this is shared in Figure 3: Performance Attributes (source: “Research Roadmap for Smart Fire Fighting”, NIST Special Pub. 1191, Pg. 218, Fig. 14.5). If any single component attributes is problematic for something impacting safety, the likelihood will be high that the device, component or system will not prevail and proliferate in the marketplace.
4) Summary Observations

This one-day “Power over the Ethernet Research Planning Workshop” at the University of New Hampshire InterOperability Laboratory provided an important focus on this topic. The event addressed research planning and facilitated dialogue among key stakeholders to identify and prioritize knowledge gaps, recommend next steps, and plan action items in support of reasonable, realistic, and safe regulatory oversight.

The overall PoE issue is relatively complex and evolving, and it represents an emerging technology with a need for further attention. This PoE Research Planning Workshop provides an important and useful review, validation and identification of gaps for Power over Ethernet. This topic is of direct interest to multiple organizations and committees responsible for the administration of model codes and standards (e.g., NFPA 70, National Electrical Code®, NFPA 72 Fire Alarm, NFPA 79 Industrial Machinery, NFPA 99 Healthcare, NFPA 730/731 Premises Security, and NFPA 1221 Emergency Services Communication Systems).

The key summary observations from this summit are the following:

1. **Regulatory Coordination**
   1.1. **Terminology**: Define and promote a universal understanding of key terminology (e.g., PoE, Power, Communication, Wire, Cable, Intelligent Coordinated Power, etc.).
   1.2. **Goals and Objectives**: Declare clear goals and objectives for all transmission applications (e.g., minimize fire and electrical hazards, maintain data integrity, etc.).
   1.3. **Occupancies and Applications**: Clarify and define occupancy requirements for applications involving PoE concepts, and categorize applications based on their criticality (e.g., COPS Critical Operations Power System, fire alarm, security, etc.).
   1.4. **Key Attributes**: Establish the performance parameters that all devices, components and associated systems need in terms of key attributes (e.g., availability, durability, maintainability, operability, reliability, stability, interoperability, compatibility, etc.).
   1.5. **Enforcement**: Indicate essential details for inspection and re-inspection, in the form of relevant and useable checklist information.
   1.6. **Products**: Facilitate the focus on “listed” products through standards that provide assurance of the products functioning as expected for their intended purpose and in support of scalable installations.
   1.7. **Document Coordination**: Generate a clear and simplified overview of the entire regulatory landscape relating to this topic. Establish an advisory council (or equivalent) to coordinate technical requirements between the codes and standards of all involved organizations.

2. **Key Technical Issues**
   2.1. **Power versus Communication**: Define, categorize and clarify requirements for the multiple options of transmitting power and communications, over one or multiple conductors (e.g., power only, communication only, communication/data/power in some combination, etc.), in coordination with defined occupancy and applications, as well as existing versus new installations.
   2.2. **Intelligent Coordinated Power**: Clarify, summarize, categorize, and address all applicable technical details for Intelligent Coordinated Power (ICP) to assure safe and effective implementation.
2.3. **Risk Analysis**: Outline an approach for conducting a comprehensive risk analysis for each applicable application, to determine the appropriate factors of safety and other key factors. Clarify the factors of safety for existing systems and approaches for purposes of a baseline.

2.4. **Data Integrity**: Address new requirements for the objective of maintaining data security and integrity (e.g., software, systems, etc.), especially in support of critical systems like COPS, fire alarm, security, etc.

2.5. **Power Supplies**: Clarify requirements for primary and back-up power supplies, contingent on occupancies, applications and other factors.

3. **Research and Data**
   3.1. **Predictive Data Analytics**: Identify and clarify data needs and prospectively collect essential data for use with predictive data analytics. Establish a centralized national data collection, to support policy and regulatory revisions.
   3.2. **Fundamental Baseline**: Conduct research in support of validated modeling and establishing theoretical fundamentals for PoE systems.
   3.3. **Knowledge Gaps**: Conduct research projects in support of all knowledge gaps identified by this workshop, including regulatory issues, technical issues, and other issues such as training, education and awareness.

4. **Training, Education and Awareness**
   4.1. **Training and Education**: Implement training and education in support of all aspects of PoE, with a special focus on supporting inspection, enforcement and commissioning.
   4.2. **Format Delivery**: Consider the use of a straight-forward yet relevant checklists and/or punch lists to facilitate third party support and enforcement.
   4.3. **Awareness Outreach**: Facilitate outreach addressing the overall virtues of emerging technologies like PoE.
   4.4. **Stakeholder Engagement**: Promote and facilitate dialogue and networking, and involve all impacted stakeholders. Address the needs of the entire ecosystem of stakeholders (e.g., designers, developers, vendors, installers, inspectors, end-users, etc.).

This workshop on PoE is an important step for addressing this issue, but it is only the beginning of a longer journey as we dive into this new era referred to in the mainstream media as the “Internet of Things.” This new era, along with the devices and technologies that support it, such as PoE, are here to stay. It is imperative that the regulatory community rises to address this new sweeping challenge.
Annex A: Workshop Attendees and Break-Out Groups Participants

The attendees to the Power over the Ethernet Workshop are summarized in Table 5.

Table 5 Workshop Attendees

<table>
<thead>
<tr>
<th>Name</th>
<th>Organization/Company</th>
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<tbody>
<tr>
<td>Andrew Berezowski</td>
<td>Honeywell</td>
</tr>
<tr>
<td>George Bish</td>
<td>MasTec North America Inc</td>
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<tr>
<td>Don Bliss</td>
<td>NFPA</td>
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<tr>
<td>David, Burkhart</td>
<td>Code Consultants, Inc.</td>
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<td>Brian Celella, Siemen Co</td>
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<td>Terry Coleman, Electrical Training Alliance</td>
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<tr>
<td>Donny Cook</td>
<td>Shelby County Dept. of Dev Services</td>
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<td>Amy Cronin, Strategic Code Solutions LLC</td>
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<tr>
<td>John D’Ambrosia, Huawei</td>
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<td>Chris Diminico, MC Communications</td>
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<td>Mark Earley, NFPA</td>
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<td>Michael Farrell III, IBEW</td>
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<td>Tom Farr, IBEW Local Union 357</td>
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<td>Rick Foster, Innovative Engineering Services, LLC</td>
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<td>Ernest Gallo, Ericsson</td>
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<td>Joe Gochal, NFPA</td>
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<td>Casey Grant, FPRF</td>
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<td>Mitch Hefter, Philips Lighting</td>
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<td>Noel Hernberger, IBEW</td>
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<td>Palmer Hickman, Electrical Training ALLIANCE</td>
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<td>Raymond Horner, Atkore International</td>
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<td>Alex Ing, NFPA</td>
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<td>Randy Ivans, UL ULC</td>
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<td>Chad Jones, Cisco</td>
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<td>Robert Jones, IEC</td>
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<td>Ward Judson, ERICO International Corporation</td>
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<td>Chad Kennedy, Schneider Electric</td>
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<td>Kyle Krueger, Milwaukee Chapter, NECA</td>
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<td>Jeff Lapak, UNH-IOL</td>
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<td>Gregg Lupaczky, Johnson Controls</td>
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<td>Wayne Moore, Jensen Hughes</td>
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<td>Mike O’Boyle, Philips Lighting</td>
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<td>Denise Pappas, Valcom, Inc.</td>
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<td>Timothy Ruiz, Code Consultants, Inc.</td>
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<td>Jeff Sargent, NFPA</td>
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<td>Masood Shariff, CommScope Inc.</td>
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<td>Glenn Shwaery, University of New Hampshire</td>
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<td>Jim Simpson, Electrical Training Alliance</td>
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<td>Bill Wayman, Jensen Hughes</td>
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<td>Lennart Yseboodt</td>
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<td>Jason Zhao, FPRF</td>
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<tr>
<td>George Zimmerman, CME consulting</td>
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The participants in each Break-Out Group are summarized in Table 6.

Table 6 Break-Out Group Participants

<table>
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<th>Group 1</th>
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<th>Group 3</th>
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<tr>
<td>Don Bliss</td>
<td>Ernie Gallo</td>
<td>Amy Cronin</td>
<td>George Zimmerman</td>
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<td>Chad Kennedy</td>
<td>Mark Earley</td>
<td>Joe Gochal</td>
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<td>Alex Ing</td>
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<td>Brian Celella</td>
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<td>Randy Ivans</td>
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<td>Wayne Moore</td>
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<td>Raymond Horner</td>
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<td>John D’Ambrosia</td>
<td>Tim Ruiz</td>
<td>Mike O’Boyle</td>
<td>Glenn Shwaery</td>
</tr>
</tbody>
</table>
Presentation 1: The Future of Power of Ethernet

THE FUTURE OF POWER OVER ETHERNET

G. Zimmerman
CME Consulting

POWER + DATA + THINGS = IOT?

- The future (and present): Anything you imagine adds extra functionality from a data connection
  - Potential to improve safety, efficiency and functionality
  - Data communications is a key enabler

- IoT = EVERYTHING + communications

9/28/2017
G. Zimmerman - NFPA Research PoE Workshop
WIRED VS. WIRELESS IOT

- Conventional wisdom: the majority of IoT will be wireless

- WIRELESS augments and drives WIRED

- 2 reasons eventually almost all wireless data enters the wired realm – POWER and BACKHAUL

- Which brings us to PoE.....

POE SINCE 1997: 802.3AF AND 802.3AT

- Commonly called “PoE” and “PoE Plus”
  - Powers on 2 pairs of a 4 pair cable (some put 2 circuits in 4 pair shared sheaths)
  - Dominant uses: Communications & Security

--- Page 28 of 104 ---
MORE POWER – 802.3BT

- Economics drives power
- Utility drives more power
- Today, what we call PoE is evolving to 802.3bt

<table>
<thead>
<tr>
<th>PoE Types and Classes</th>
<th>2-Pair PoE+ – Type 2</th>
<th>2-Pair PoE – Type 1</th>
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<tbody>
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<td>Class</td>
<td>0</td>
<td>1</td>
<td>2</td>
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<td>15.4</td>
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<tr>
<td>PD Power (W)</td>
<td>13</td>
<td>3.84</td>
<td>6.49</td>
</tr>
</tbody>
</table>

4-Pair PoE – Type 3

4-Pair PoE Type 4

POE MATTERS EVEN AS WIRELESS HAPPENS

- Desktop computers disappear or go wireless
  - When high rate data can be provided wirelessly, what drives copper infrastructure?

- Varied Applications:
  - Lighting, Signage
  - Access Control, Security
  - Safety systems, alarms, Intercoms
  - Reliable networking infrastructure
    - "Class N"
    - Backhaul for wireless

- Anything that is fixed, needs power and can source or sink information

9/26/2017
SAFE POE, “NOT-POE” AND THE INDUSTRY’S EFFORTS TO DISTINGUISH THE TWO

STANDARDS-BASED POE RESPECTS THE NEC

- **Plug-and-Play**
  - PSEs “detect” PDs: Won’t power non-PoE devices
  - Classification: PSEs determine power needed by PD
- **Safety**
  - Safe Extra Low Voltage (SELV)/Limited Power Source (LPS) PSEs (<60 V, <100 VA/circuit)
  - Current limits based on classification
  - Meets Table 11(B) limits
  - Power cutoff on faults
  - Polarity insensitive

Upper limit allows for transients

Lower limit supports max. average power demand, representative of heating potential
“PASSIVE POE” OR “NOT-POE” – THE FUTURE?

- When is the application safe, standardized power and when is it just a makeshift power source on LAN cabling?

SUCCESS OF SAFE POWER SOURCES BREEDS LOW-COST ALTERNATIVES

- No detection to protect devices not wanting power
- No classification to limit current provided
- No standardization of voltage (Provision of 5V, 12V or 24V saves conversion costs)
- No inherent current/power limiting – direct coupling of any source to a line
WHAT IS THE INDUSTRY DOING ABOUT IT?

- **IEEE**: Standardizing safe power delivery
  - IEEE P802.3bt - “the last standard for (4-pair) PoE”
- **TIA**: Standardizing cabling practices
  - TSB-184-A “Guidelines for Supporting Power Delivery Over Balanced Twisted-Pair Cabling”
    * Considering inclusion in next rev of ANSI/TIA-568
- **Ethernet Alliance**: Certifying 802.3-based PoE
  - Identifies interoperable PSEs, PDs
  - Includes power class for PDs & PSEs
  - First certification plugfest in progress

---

EMERGING: SINGLE-PAIR
THE RISE OF SINGLE-PAIR

- Automotive needs initiated the development of new single-pair Ethernets – “BASE-T1” – and powering – “PoDL”
- Market adoption has started in industrial and building automation segments

- The newest, 802.3cg, is targeted to provide single-pair connections replacing fieldbus and other industrial systems

IEEE 802.3 SINGLE PAIR STANDARDS

- **IEEE Std 802.3bw-2015 – 100BASE-T1**
  - 100 Mbps full duplex at 66.67MBaud
  - “over a single balanced twisted-pair cable up to 15m in length”
  - 4 inline connectors and two mating connectors
  - 90 to 110 ohm characteristic impedance

- **IEEE Std 802.3bp-2016 – 1000BASE-T1**
  - 1000 Mbps full duplex at 750 MBaund
  - Single balanced twisted pair, 2 link segments:
    - 15 meter (required)
    - 40 meter (optional)

- **IEEE P802.3bu – Power over Single Pair Data Lines**
  - Compatible with 802.3bw and 802.3bp
  - Requires ≤6.5 ohm DC loop resistance (6 ohms for 12V unregulated classes)
  - Amperages range from 97 mA to 1360 mA (50 Watts)
**STANDARD POWERING ON 2 WIRES: PoDL**

- Single-pair – 802.3bu-2016 “PoDL”
  - Developed for automotive Ethernet, but used in IoT and industrial applications

<table>
<thead>
<tr>
<th>Class</th>
<th>12V unreg</th>
<th>12V reg</th>
<th>24V unreg</th>
<th>24V reg</th>
<th>48V reg</th>
</tr>
</thead>
<tbody>
<tr>
<td>V(max) at PSE</td>
<td>18V</td>
<td>18V</td>
<td>18V</td>
<td>36V</td>
<td>36V</td>
</tr>
<tr>
<td>V(min) at PSE</td>
<td>5.6V</td>
<td>5.77V</td>
<td>14.4V</td>
<td>14.4V</td>
<td>11.7V</td>
</tr>
<tr>
<td>I(max)</td>
<td>0.10A</td>
<td>0.23A</td>
<td>0.25A</td>
<td>0.47A</td>
<td>0.10A</td>
</tr>
<tr>
<td>Power at PD</td>
<td>0.5W</td>
<td>1W</td>
<td>3W</td>
<td>5W</td>
<td>1W</td>
</tr>
</tbody>
</table>

---

**IEEE P802.3CG KEY CHARACTERISTICS**

- 2 types: Short reach and up to 1 km distance, on a single pair of wiring
  - Can survive fault conditions – even harsh automotive and industrial
  - Energy efficient: Low power as well as quiet and standby modes
- Can be compatible with Intrinsically Safe operation
- Supports optional line powering (PoDL and possible extensions)
- Standard expected in 2019
VARIED USE CASES ALREADY IN .3CG

- Short:
  - In-cabinet, chassis
  - Vehicles
  - Multipoint topologies

- Medium:
  - Industrial pods (5-40m)
  - Building control networks (50-100m)
  - Process control "spurs" (200m)

- Long:
  - Process control trunks (1km)
  - Building automation trunks (500m)
  - Elevator shafts

- Gauge likely based on power needs

WITH SUCCESS COMES MORE SUCCESS...

- Every time I turn around, someone has a new use....
  - Elevators
  - COPS?, Alarms?

- Managed power and data benefits safety
INTELLIGENT COORDINATED POWER AND ENERGY MANAGEMENT SYSTEMS

THE FUTURE: INTELLIGENT COORDINATED POWER (ICP)

- ICP – it’s not just for juggaloes anymore...

- Intelligent Coordinated Power
  - Saves energy
  - Saves cost in overprovisioning infrastructure
  - Prevents safety problems
  - Can prevent 'all lines / max current' scenario

- Cisco EnergyWise: Integrated w/PoE
  - Manages energy per device in a network
  - Manages PoE distribution (and others) in groups based on resources

- An Energy Management System...
- Working with Every Network

*Insane Clown Posse
ENERGY MANAGEMENT – IT’S ALREADY HERE

- **EMS’s are in Article 750**

750.2 Definitions. For the purpose of this article, the following definitions shall apply.

- **Control.** The predetermined process of connecting, disconnecting, increasing, or reducing electric power.
- **Energy Management System.** A system consisting of any of the following: a monitor(s), communications equipment, a controller(s), a timer(s), or other device(s) that monitors and/or controls an electrical load or a power production or storage source.
- **Monitor.** An electrical or electronic means to observe, record, or detect the operation or condition of the electric power system or apparatus.

---

LINKING POWER MANAGEMENT TO THE INFRASTRUCTURE

- **Automated infrastructure management**
  - As-built or auto-sensed configurations
  - Which cable goes to where
  - Managed to a network database

- **Linked to the EMS?**
FUTURE POWER SOURCES - SMART SAFETY

- Build the GFCI into the power source
- Sense faults on a micro-time scale and interrupt
- The end of “low voltage” limits?

![GFCI Trip Characteristics](image)

BACK TO TODAY: WHERE WE ARE IN THE NEC WITH POE

NEC 2017 and the PoE Task Group
STUFF WE THINK WE’VE RESOLVED
725.121, 725.144, AND 840.160

- Labeling a power source (725.121)
  - Labeling on each port of a high-density PoE power source is impractical
  - Labeling groups of ports with the same output capability is feasible
  - Is a patch panel port connected to a PSE by a cable, a “power source port”?
- Heating is proportional to the square of current, not the power delivered (840.160)
  - PoE Task Group worked carefully to reflect the relationship between multiple pairs in the same cable – came up with “nominal current” and limiting by that rather than power
- The cabling outlets are the permanent fixture, but are reconfigurable
  - When power + data and data-only are mixed, how does the installer/maintainer, inspector or user tell a data outlet from a data + power outlet with a PoE power?

CURRENT ISSUES WE HAVEN’T RESOLVED

- Ampacity varies based on 2 pair power vs. 4 pair power per 725.144
  - How to label if the ampacity is source-dependent?
- How do we treat multiple tied bundles lying together in a close space?
  - Does removing an outer tie or wrap make each a single bundle?
  - What about multiple tied bundles lying together in a conduit, but without a tie?
  - A “Bundle” isn’t defined
- What about narrower than 26AWG wires? (28AWG cords are here, 30AWG is coming)
  - 2017 NEC says “under engineering supervision” – problem is, there are currently no published industry-consensus guidelines or standards for < 26AWG
- What about equipment cords? (covered under 310.15(B)(2)?)
- Do 725.144 and 840.160 apply to other-than 4-pair LAN cable?
  - 25 or 50 pair cabling is used for high density trunks
DEVELOPING ISSUES AS TECHNOLOGY EMERGES AND MATURES

- How should the code treat single-pair powering
  - 4 potentially independent circuits in 4-pair LAN cabling
  - Can run on a variety of cable types (single pair, 25pair, 50 pair...)
  - How will materials, cabling and distribution systems (e.g., cable runs) differ for this technology?

- How can the code enable and encourage safe, efficient energy management systems?
  - What characteristics are desired and required?

- As PoE evolves in the mainstream consumer market, how do we keep from getting crushed by the workload
  - These often have small numbers of ports, unlikely to ever create an issue
    - Can we exempt small installations?, Do we classify them by port count, or by total power delivered?
  - Are there differences based on occupancy types?

THANK YOU!
STANDARDS & SAFETY

DOING ALL WE CAN TO PREVENT, PREDICT AND PROTECT

3 October 2017 - Donald P Bliss| Vice President for Field Operations

OUR VISION

We are the leading global advocate for the elimination of death, injury, property and economic loss due to fire, electrical and related hazards.
OUR MISSION

We help save lives and reduce loss with information, knowledge and passion.

INFORMATION AND KNOWLEDGE
The Role of Standards

- Industry best practice
- Interoperability
- Basis for regulation
- Level playing field
- Risk management
- Consumer protection
- Reduction of property and economic loss
- Life safety

The U.S. Standards Landscape

- American National Standards Institute (ANSI)
- Open & transparent processes
- Consensus based
- Product-oriented products
- Safety-oriented documents
- Combination documents
Standards for Safety

- Balance society’s:
  - Tolerance for risk
  - Willingness to commit resources
- Example: Sprinkler systems in hi-rise buildings

National Model Codes

- 1897
  - National Electrical Code
- 1905
  - Recommended National Building Code
Integrated System

Standards Platform

Community Risk Reduction
Urban planning & fire protection capabilities

Building & Occupant Safety
Building design, construction, operation & maintenance

Components
Use of tested & certified building components
Why do codes & standards change?

- Catastrophic event or pattern of events
- Research findings
- New technologies
- New design concepts
- Changes in societal risk acceptance

Regulatory Authority

- States
  - Statutory adoptions
  - Administrative Rulemaking
- Local Governments
  - Ordinances
  - Regulations
The Federal Role

- OMB Circular A-119
- National Technology Transfer & Advancement Act of 1995

KEY TERM

- “Authority Having Jurisdiction” (AHJ)
  - Vested with responsibility to enforce the code or standard
The University of New Hampshire InterOperability Laboratory (UNH-IOL)

Introduction to PoE and PoE Certification Testing at UNH-IOL

www.iol.unh.edu

Agenda

- Introduction to the UNH-IOL
  - Information about the tour
- PoE as it exists today
  - Non-Standardized vs Standardized
  - IEEE 802.3 (.af/.at)
- Ethernet Alliance PoE Certification Testing
About the speaker — UNH-IOL

University of New Hampshire

About the speaker — UNH-IOL

- Industry leading 3rd-party test facility for data, telecom and storage networking technology & consumer electronics
- 100% funded by commercial industry
- 28,000 sq. ft lab facility
- 5,000 sq. ft pre-wired space dedicated to Plugfests
About the speaker — UNH-IOL

- Member Involvement

- Industry Involvement
Agenda

- Introduction to the UNH-IOL
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PoE Today

- Standards Based Solutions
  - IEEE 802.3
  - Several IEEE “based” standards

- Non-Standard Solutions
  - Low Safety
  - Little compatibility
    - Application of direct DC or AC voltage directly onto the wiring system
    - Usually without any circuit protection
Examples

- Many examples of non-conformant equipment
- Requires IT staff to guess at what is attached to any given port

More Examples
**IEEE 802 PoE Today**

- 2 Current IEEE Types
  - IEEE 802.3af (Type 1)
    - Up to 13W at Powered Device
  - IEEE 802.3at (Type 2)
    - Up to 25.5W at PD

- Both only use 2 pairs!

---

**Interoperable Types and Classes**

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<td>6.49</td>
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</table>

4-Pair PoE – Type 3

4-Pair PoE Type 4
PoE Applications Today

- IP Phones
- Security Scanners
- IP/Security Cameras
- Wireless Access Points

Potential Future Applications

- Stepper Motors for Pan/Tilt Cameras and Industrial
- Lighting / HVAC Control Systems
- Point of Sale Systems
- Medical Stations / Thin Clients
Detection and Classification

The open circuit (idle state) is the PSE probing to see if a PD is connected.

Detection is the process for the PSE to determine if there is a PD plugged into it.

Classification tells the PSE how much power to allocate for the PD.

Power on occurs when classification has been completed and a valid voltage has been applied to the PI.

Detection

- PD must present a valid resistance ("Detection Signature") at the PI to receive power from a PSE.
- To measure this resistance, the PSE sends a detection pulse with a voltage within the valid detection range (2.80V to 10.0V) and measures the resulting current draw from the potential PD.
- The PSE must make at least two measurements, each pulse having at least a 1V difference to the next.
- The resistance can be calculated using the equation:

\[ R = \frac{(V_2 - V_1)}{(I_2 - I_1)} \]

- This process must not take longer than 500 ms.
- A PSE must accept a detection signature between 19.0kΩ and 26.5kΩ, and reject a detection signature <15.0kΩ or >33.0kΩ. Any value between the "must accept" and "must reject" can be either accepted or rejected by the PSE.
Detection Example

This figure is the detection sequence from a PSE captured on an oscilloscope. You will notice the two detection pulses with a difference of 1.61V, both of these pulses are within the range of 2.80V to 10.0V. A valid signature at the first pulse would result in a current draw between 0.31mA(19kΩ) and 0.22mA(26.5kΩ). For the second pulse, the current draw would need to be between 0.21mA(19kΩ) and 0.15mA(26.5kΩ).

Clause 33 Classification

- The interrogation and power classification function is intended to establish “mutual identification”, which is the mechanism that allows a Type 2 PD (a PD that can draw up to 25.5 W of power) to differentiate Type 1 PSEs from Type 2 PSEs. Similarly, mutual identification allows Type 2 PSEs to differentiate between Type 1 and Type 2 PDs.
- PDs or PSEs that do not implement classification will not complete mutual identification. In these cases, they can only perform as Type 1 devices.
- There are two types of classification: physical layer classification and data link layer classification (DLLC).
1-Event Physical Layer Classification

- In this example, you can see that after detection and before power on, a 1-Event classification pulse was measured to be 17.58V. Because this is within the range of 15.5 and 20.5V, it can be determined that this was indeed a 1-Event classification pulse.

PSE 2-Event Physical Classification

- In this example, after detection and before power on, you can see a 2-Event classification sequence.
  - The first class event voltage was at 17.05V.
  - The first mark event voltage was at 8.14V.
  - The second class event voltage was at 17.04V.
  - The second mark event voltage was at 8.14V.
  - Both class event voltages were within the correct range (15.5-20.5V).
  - Both mark event voltages were within the correct range (7.0-10.0V).
Data Link Layer Classification (DLLC)

- Addition control and classification functions are supported using Data Link Layer Classification.
- Type 2 PDs that require more than 13.0 W support DLLC, but DLLC is optional for PSEs.
- DLLC is a more precise way for PSEs to allocate power to PDs.
- DLLC allows for a PD to reduce its allocated power to a specific value.
- The allocated power can also be increased, but not past the limit of the PDs physical layer classification.

4-Pair PoE Multiple-Event Classification

Figure 146B-14 shows a Type 4 PSE performing a Multiple-Event Physical Layer classification with a Class 8 PD. Autoclass is not shown in this timing diagram.

*Autoclass is an extension of physical layer classification that PSEs may implement. The purpose is to allow the PSE to determine the actual maximum power draw of the connected PD.
Additional Safety Features

- Polarity insensitive
- Short Circuit / Overload Detection
- Current inrush limits
- Maintain power signatures
- Safe Extra Low Voltage (SELV) Designed
  - PSE supplies are < 60V and current is limited

Agenda

- Introduction to the UNH-IOL
  - Information about the tour
- PoE as it exists today
  - Non-Standardized vs Standardized
  - IEEE 802.3 (.af/.at)
- Ethernet Alliance PoE Certification Testing
Identifying Program Needs

- Products, based on existing standards (802.3af and 802.3at), have been shipping for 10 years.
- Need to ensure existing Interoperability and Safety are met
- Low hurdle to market deployment for rapid establishment and brand recognition
- Enable PoE adoption into non-traditional IT application spaces
- New IEEE 802.3 PoE standard will create new complexities to communicate

PoE Certification Program Intro

- Global Branding for IEEE 802.3 PoE Products
- Ethernet Alliance Defined Program and requirements
  - Two “Generation” approach –
    - Generation 1 – 802.3af / 802.3at
    - Generation 2 – 802.3bt (4 Pair PoE)
- Allows for both 1st and 3rd Party Testing
- Logo protected via a Certification Mark License Agreement (CMLA)
Conformance Testing Based

- Test cases are based on the IEEE 802.3 shall statements
  - PICS (Protocol Information Conformance Statement)
- Tests were evaluated on two impact metrics
  - Safety and Interoperability
- Test cases cover
  - Detection, Classification, Power on Voltage
  - Short Circuit, Overload, and MPS
  - Timing, etc

1st Party Testing (Testing done by Manufacturers)

- Restrictions
  - Limited to members of the Ethernet Alliance only.
  - Requires auditing through a UNH-IOL program where 1st party testing are periodically verified for accuracy.
  - Only permitted on Ethernet Alliance / UNH-IOL approved 3rd party test equipment.

* Note - Non-members of the Ethernet Alliance can still get equipment certified, but must have testing performed at UNH-IOL.
Market Surveys and Audits

- Program allows for periodic market surveys to ensure non-conformant products are not using the certification mark.
CABLE STUDY

Chad Jones
Cisco

Study Description

• Panduit, Cisco, and Philips partnered to study temperature rise in actual cable bundles to compare to the simulated bundle testing that has been previously conducted.
• A quick description of the test and summary of the results follows.
Current Required for Interoperability

- The standard must assume worst case operating parameters to maximize interoperability. This results in the following maximum port current per Class:

<table>
<thead>
<tr>
<th>Class</th>
<th>Vpse (V)</th>
<th>Ppse (W)</th>
<th>Iport (A)</th>
<th>Pair (A)</th>
<th>Conductor (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>50</td>
<td>45</td>
<td>0.900</td>
<td>0.450</td>
<td>0.23</td>
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<tr>
<td>6</td>
<td>50</td>
<td>60</td>
<td>1.200</td>
<td>0.600</td>
<td>0.30</td>
</tr>
<tr>
<td>7</td>
<td>52</td>
<td>75</td>
<td>1.442</td>
<td>0.721</td>
<td>0.36</td>
</tr>
<tr>
<td>8</td>
<td>52</td>
<td>90</td>
<td>1.731</td>
<td>0.866</td>
<td>0.43</td>
</tr>
</tbody>
</table>

- ALL cable plant testing to this point focused on the worst case conductor current

PoE: a Voltage Source with Constant Power PDs

- A PoE system rarely supplies worst case current. In fact, a system NEVER supplies worst case current on any significant number of circuits.

  Cable current (I_{cable}) is determined by:
  - PSE Port Voltage (Vpse)
  - Cable resistance (R_{cable})
  - PD power (P_{pd})

- For a system to supply maximum I_{cable}, each of these 3 parameters need to be precisely at worst-case.

- The equation for PoE power delivery:

\[
I_{cable} = \frac{V_{pse} - \sqrt{V_{pse}^2 - 4(R_{cable})(P_{pd})}}{2(R_{cable})}
\]
802.3bt Worst Case

1.73 A (≈0.433 A/conductor)

52V

Worst case channel of 6.25 Ω
Load: constant power of 71.3 W (Class 8)

Type 4, Class 8 PDs may take a maximum of 71.3 W.
With the lowest allowed PSE voltage of 52 V, and the worst supported channel resistance of 6.25 Ω, a current of 1.73 A flows through the cable.

1.73 A, or 0.433 A per conductor, is the highest nominal current that can flow in a compliant system.

Constant Current, 1.73 A

1.73 A (≈0.43 A/conductor)

52V

Channel: 24 AWG UTP
Load: constant current of 1.73 A

If we apply this current through 'real cable' (AWG 24), the resulting delivered power is 78 W.
This is not a compliant or valid PoE system. PDs don’t do this.
Using a current of 1.73 A results in a power density of 123 mW/m.

Rch based on resistivity of 24 AWG solid copper at 20° C.
Constant Power, Class 8

Channel: 24 AWG UTP
Load: constant power of 71.3 W (Class 8)

The correct way to determine power dissipation / heating for any given cable is to use a constant-power sink as the load, and a voltage source as the supply.

For 24AWG cable (100m), 1.56A will flow, with a power density of 100mW/m.
If the cable were 50m, 1.46A will flow, with power density of 87mW/m.
If the cable were 20m, 1.4A will flow, with power density of 80mW/m.

Current Drawn By A Constant Power Load

- The currents drawn by each new 4P class with an interoperable R_cable and typical R_cable of 22-24 AWG at 40C

<table>
<thead>
<tr>
<th>#AWG</th>
<th>mOhm/m</th>
<th>Class 8</th>
<th>Class 7</th>
<th>Class 6</th>
<th>Class 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interoperable</td>
<td>62.5</td>
<td>52</td>
<td>52</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>24</td>
<td>62</td>
<td>51.8</td>
<td>1.442</td>
<td>1.200</td>
<td>1.034</td>
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<tr>
<td>23</td>
<td>35</td>
<td>1.583</td>
<td>1.345</td>
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<td>22</td>
<td>28</td>
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<td>1.307</td>
<td>1.106</td>
<td>0.965</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.491</td>
<td>1.281</td>
<td>1.086</td>
<td>0.951</td>
</tr>
</tbody>
</table>
Current Drawn By A Constant Power Load, per conductor

- The currents drawn by each new 4P class with an interoperable R_cable and typical R_cable of 22-24 AWG at 40C

<table>
<thead>
<tr>
<th>#AWG</th>
<th>mOhm/m</th>
<th>I_cable</th>
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</thead>
<tbody>
<tr>
<td>Interoperable</td>
<td>62.5</td>
<td>0.433</td>
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<tr>
<td>24</td>
<td>44</td>
<td>0.393</td>
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<tr>
<td>23</td>
<td>35</td>
<td>0.382</td>
</tr>
<tr>
<td>22</td>
<td>28</td>
<td>0.373</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class</th>
<th>V_pse</th>
<th>Ppd</th>
</tr>
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<tbody>
<tr>
<td>8</td>
<td>52</td>
<td>71.3</td>
</tr>
<tr>
<td>7</td>
<td>52</td>
<td>62</td>
</tr>
<tr>
<td>6</td>
<td>50</td>
<td>51</td>
</tr>
<tr>
<td>5</td>
<td>50</td>
<td>45</td>
</tr>
</tbody>
</table>

Comparing Power Density

- Power Density is simply the power dissipated in the cable per unit length

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Channel</th>
<th>Power Density (mW/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interoperable Class 8</td>
<td>6.25 Ohm 4P</td>
<td>187</td>
</tr>
<tr>
<td>1.73A Constant Current</td>
<td>100m 24AWG</td>
<td>123</td>
</tr>
<tr>
<td>71.3W Constant Power</td>
<td>100m 24AWG</td>
<td>100</td>
</tr>
<tr>
<td>71.3W Constant Power</td>
<td>50m 24AWG</td>
<td>87</td>
</tr>
<tr>
<td>71.3W Constant Power</td>
<td>100m 24AWG, 40C</td>
<td>110</td>
</tr>
<tr>
<td>71.3W Constant Power</td>
<td>100m 23AWG, 40C</td>
<td>82</td>
</tr>
<tr>
<td>71.3W Constant Power</td>
<td>100m 22AWG, 40C</td>
<td>62</td>
</tr>
</tbody>
</table>
**Constant Current**

- The bundle is constructed of a single cable looped back on itself to get the desired bundle size.
- The 8 individual conductors are connected to form a long series connection. A current source generates the desired current.

**Constant Power**

- The bundle is constructed out of separate cables. Each cable is supplied by a voltage source, at the other end of the cable a constant power sink draws the desired amount of power.
- The current drawn is determined by the source voltage, cable resistance and the amount of power sunk.
**Temperature Test Setup**

- 9,120m of cable
- 768 patch cords
- 384 jacks
- 69 Thermocouples
- Scanned every 30s
- (5 hr. stability time)

- 10 Cisco 48-port switches (3850)
- 48 Telma Power Supplies
- 1 Intel EER (1 Gbps data rate)
- 240 Power inject/pass-thru/terminal Units

**Test Conditions**

Thermocouple placement within Bundle cross section

Thermocouple Placement in Cable Bundle (Lengths in m)
Test Conditions

All conditions run in open air and in conduit in a constant temperature/humidity environment.

For each Class 4 through 8:
  • Constant Current at maximum current
  • Constant Current at average current
  • Constant Power at $V_{PSE}$ minimum
  • Constant Power at $V_{PSE}$ nominal
  • Constant Power Tracked
    (Constant power on 100 m cables. Current on all other cables matched to current in 100 m cables)

Constant Current = 2,000 mA

52 total test conditions

Powering methods

CL4:CP:54V = Class 4 : Constant Power : PSE voltage 54V
This should be considered a typical PoE case (with Class 4 loads), with constant power PDs using a distribution of cable lengths as described earlier.

CL4:CP:50V = Class 4 : Constant Power : PSE voltage 50V
The same as above, but with the lowest allowed PSE voltage. For Class 7 and 8, the lowest voltage allowed is 52V

CL4:CC:600mA = <Class 4 equivalent> : Constant Current : Current in mA
A fixed current was sourced through the cable. This current denotes the total 4-pair current. For each Class, two CC tests are performed: the lower current represents the calculated average current corresponding with the lowest PSE voltage. The higher current is the theoretical maximum current at the lowest PSE voltage and highest channel resistance.

CL4:CP:Tracked = Class 4 : Constant Power : Tracked current
The sources “track” the current level of the source that powers the longest cable in the bundle (which itself is in Constant Power mode). This emulates as if every cable in the bundle is 100m long.
Summary 192 bundle tests

- Type 3 power levels (9.7 KW of delivered power) are generally below a 15C rise (with the exception of the tracked method at 17C)
- Type 4 power levels (13.7 KW of delivered power) are all well above 15C rise
- The extreme corner case (Class 8 PD, conduit, 192 powered cables, lowest PSE voltage, all 100 m long) leads to a 34C rise.
- Type 4 temperature rise is between ~20 deg C and ~35 deg C with 192 powered cables in the bundle.
- With Type 4 power levels, small changes in conditions lead to large differences in temperature.
- Ethernet (1000BASE-T) operation was not impacted during any test

CASE STUDY
Modern Hospital

Chad Jones
Cisco
The Building

- Newer construction (completed in late 2016)
- 212,000 sq ft
- Five stories
- PoE powers IP security cameras, IP Phones, APs, Hill-Rom Nurse Call, Patient Monitoring, Kronos Timeclocks, and Automation
  - 883 total PDs
  - Number of:
    - IP Phones (mostly Avaya 9611G): 351
    - APs (Cisco 3702): 148
    - Nurse Call (RCB2 UPOE): 208
    - Cameras (Vivotek FE8191, Axis PTZ), Patient Monitoring, Kronos, Automation: 176

The Technology Distribution Rooms (TDR)

- Each floor has a TDR, each one is nearly identical
- Each TDR has two Cisco 4510’s with 672 ports total
- Each 4510 has two 6kW power supplies (provides power for the 4510 and for PoE)
The TDR Cabling

- Most is 23AWG CAT6a
- Some is 24AWG CAT6 or Cat5e

The Building Cabling

<table>
<thead>
<tr>
<th>Total Cables in Fluke Reports</th>
<th>4504</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Length</td>
<td>691472 ft</td>
</tr>
<tr>
<td>Average Length</td>
<td>153.6 ft</td>
</tr>
<tr>
<td>Shortest Cable (one of them)</td>
<td>6 ft</td>
</tr>
<tr>
<td>Longest Cable (two of them)</td>
<td>373 ft</td>
</tr>
<tr>
<td>Number of Cat5e Cables</td>
<td>668</td>
</tr>
<tr>
<td>Number of Cat6 Cables</td>
<td>4</td>
</tr>
<tr>
<td>Number of Cat6a Cables</td>
<td>3832</td>
</tr>
</tbody>
</table>

- 614 of the 668 Cat5e cables (92%) is 50 ft or shorter, average of 26.5 ft
- Shortest Cat 6a is 24 ft, average of 174 ft
Isn’t everything bundled together?

Bundles are naturally formed in groups of about 24
Bundles of 24
Don’t the cables leave the TDR in big bundles?

Cable Runway and Exit

- Cable laid in trays, exit through STI NEZ33 Smoke Sleeves.
- 6.7 in² cable loading area, estimated 55 cable capacity
Don’t I have to allocate 60W (0.3A) per port?

PoE Reported by the Switches
- Switch console reports ‘allocated power’. This is based on worst case port voltage, cable length and channel resistance.
- This matches the power calculated by the PD reported power.
- Yields 1.37kW of power dissipated in the cabling

<table>
<thead>
<tr>
<th>Total Reported Power</th>
<th>Cable loss (= PSE-PD)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PD</strong></td>
<td><strong># of PDs</strong></td>
</tr>
<tr>
<td>60W</td>
<td>1</td>
</tr>
<tr>
<td>35.4W</td>
<td>208</td>
</tr>
<tr>
<td>30W</td>
<td>13</td>
</tr>
<tr>
<td>16.8W</td>
<td>146</td>
</tr>
<tr>
<td>15.4W</td>
<td>171</td>
</tr>
<tr>
<td>9W</td>
<td>2</td>
</tr>
<tr>
<td>4W</td>
<td>342</td>
</tr>
</tbody>
</table>

14285.4  1368.34
Allocated Power versus Actual Power

- There are only 127 cables (2.8%) longer than 280 ft (85m) that could get near theoretical worst case.

**What is realistic?**

For this, I analyzed the cable plant.

<table>
<thead>
<tr>
<th>Length (m)</th>
<th>#</th>
<th>%</th>
<th>Avg L</th>
</tr>
</thead>
<tbody>
<tr>
<td>-10</td>
<td>480</td>
<td>10.66%</td>
<td>6</td>
</tr>
<tr>
<td>10-20</td>
<td>250</td>
<td>5.55%</td>
<td>15</td>
</tr>
<tr>
<td>20-30</td>
<td>345</td>
<td>7.66%</td>
<td>25</td>
</tr>
<tr>
<td>30-40</td>
<td>559</td>
<td>12.41%</td>
<td>35</td>
</tr>
<tr>
<td>40-50</td>
<td>679</td>
<td>15.08%</td>
<td>45</td>
</tr>
<tr>
<td>50-60</td>
<td>738</td>
<td>16.39%</td>
<td>55</td>
</tr>
<tr>
<td>60-70</td>
<td>723</td>
<td>16.05%</td>
<td>65</td>
</tr>
<tr>
<td>70-80</td>
<td>499</td>
<td>11.08%</td>
<td>75</td>
</tr>
<tr>
<td>80-90</td>
<td>189</td>
<td>4.20%</td>
<td>85</td>
</tr>
<tr>
<td>&gt;90</td>
<td>42</td>
<td>0.93%</td>
<td>97</td>
</tr>
</tbody>
</table>

Next step is to calculate PSE power using the PD power, the PSE voltage and actual cable resistance.

Steps to calculate actual power:

- Calculate the PSE power for each PD with the lengths from the cable plant analysis (Calculated PSE Power slide)
- Calculate the number of PDs of each power at each length from the cable plant analysis (Assumed Cable Distribution slide)
- Calculate the total by multiplying the number of PDs by the calculated PSE power (Constant Power Delivery slide)
- Calculate the cable power dissipated by subtracting the PD Power from the Calculated PSE Power (Constant Power Delivery slide)
Calculated PSE Power

Calculated PSE Power based on PD power using Vpse of 53V, R_cable 0.044Ohm/m, and cable length distribution based on the analysis

<table>
<thead>
<tr>
<th>Assumed Length</th>
<th>6</th>
<th>15</th>
<th>25</th>
<th>35</th>
<th>45</th>
<th>55</th>
<th>65</th>
<th>75</th>
<th>85</th>
<th>97</th>
</tr>
</thead>
<tbody>
<tr>
<td>PD Power</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>51W</td>
<td>51.24</td>
<td>51.62</td>
<td>52.07</td>
<td>52.51</td>
<td>52.98</td>
<td>53.46</td>
<td>53.96</td>
<td>54.49</td>
<td>55.01</td>
<td>55.72</td>
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<tr>
<td>32.3W</td>
<td>32.37</td>
<td>32.52</td>
<td>32.69</td>
<td>32.86</td>
<td>33.04</td>
<td>33.22</td>
<td>33.40</td>
<td>33.60</td>
<td>33.78</td>
<td>34.03</td>
</tr>
<tr>
<td>15.4W</td>
<td>15.42</td>
<td>15.49</td>
<td>15.53</td>
<td>15.57</td>
<td>15.61</td>
<td>15.65</td>
<td>15.69</td>
<td>15.73</td>
<td>15.78</td>
<td>16.8W</td>
</tr>
<tr>
<td>8.6W</td>
<td>8.61</td>
<td>8.63</td>
<td>8.66</td>
<td>8.68</td>
<td>8.71</td>
<td>8.73</td>
<td>8.76</td>
<td>8.78</td>
<td>8.81</td>
<td>8.84</td>
</tr>
<tr>
<td>3.9W</td>
<td>3.90</td>
<td>3.91</td>
<td>3.91</td>
<td>3.92</td>
<td>3.92</td>
<td>3.93</td>
<td>3.93</td>
<td>3.94</td>
<td>3.94</td>
<td>3.95</td>
</tr>
</tbody>
</table>

Theoretical PSE power:
- 60W
- 35.4W
- 30W
- 15.4W
- 9W
- 4W

Assumed Cable Distribution

<table>
<thead>
<tr>
<th>avg. L.</th>
<th>6</th>
<th>15</th>
<th>25</th>
<th>35</th>
<th>45</th>
<th>55</th>
<th>65</th>
<th>75</th>
<th>85</th>
<th>97</th>
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<tbody>
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<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>32.3W</td>
<td>22</td>
<td>12</td>
<td>16</td>
<td>26</td>
<td>31</td>
<td>34</td>
<td>33</td>
<td>23</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>25.5W</td>
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<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>15.4W</td>
<td>16</td>
<td>8</td>
<td>11</td>
<td>18</td>
<td>22</td>
<td>24</td>
<td>23</td>
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</tr>
<tr>
<td>13W</td>
<td>18</td>
<td>9</td>
<td>13</td>
<td>21</td>
<td>26</td>
<td>28</td>
<td>27</td>
<td>19</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>8.6W</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3.9W</td>
<td>36</td>
<td>19</td>
<td>26</td>
<td>43</td>
<td>52</td>
<td>56</td>
<td>55</td>
<td>38</td>
<td>14</td>
<td>3</td>
</tr>
</tbody>
</table>
### Constant Power Delivery

**Total power (Calculated PSE power * cable distribution)**

<p>| | | | | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
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<th></th>
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<th></th>
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<tbody>
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<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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<td>54.49</td>
<td>0.00</td>
<td>0.00</td>
<td>54.49</td>
</tr>
<tr>
<td>712.03</td>
<td>350.18</td>
<td>522.05</td>
<td>854.44</td>
<td>1024.28</td>
<td>1129.52</td>
<td>1102.36</td>
<td>722.70</td>
<td>304.05</td>
<td>68.06</td>
<td>6880.66</td>
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<td>25.56</td>
<td>25.65</td>
<td>25.76</td>
<td>51.73</td>
<td>51.95</td>
<td>52.17</td>
<td>52.40</td>
<td>26.31</td>
<td>26.43</td>
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<td>266.75</td>
<td>123.64</td>
<td>170.44</td>
<td>279.58</td>
<td>342.57</td>
<td>374.64</td>
<td>359.93</td>
<td>251.03</td>
<td>94.37</td>
<td>15.78</td>
<td>2258.72</td>
</tr>
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<td>234.55</td>
<td>117.71</td>
<td>170.77</td>
<td>277.01</td>
<td>344.45</td>
<td>372.54</td>
<td>360.81</td>
<td>255.04</td>
<td>94.37</td>
<td>27.12</td>
<td>2254.38</td>
</tr>
<tr>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>17.56</td>
<td>0.00</td>
<td>0.00</td>
<td>17.56</td>
</tr>
<tr>
<td>140.50</td>
<td>74.23</td>
<td>101.71</td>
<td>168.42</td>
<td>203.93</td>
<td>219.89</td>
<td>216.23</td>
<td>149.58</td>
<td>55.18</td>
<td>11.84</td>
<td>1341.52</td>
</tr>
</tbody>
</table>

**Cable power (Calculated PSE power – PD power)**

|   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 3.487 | 0.000 | 0.000 | 3.49 |
| 2.090 | 2.941 | 6.727 | 15.417 | 23.914 | 32.337 | 37.448 | 30.489 | 13.622 | 3.518 | 168.50 |
| 0.059 | 0.153 | 0.261 | 0.735 | 0.954 | 1.173 | 1.396 | 0.813 | 0.926 | 0.000 | 6.47 |
| 0.345 | 0.443 | 1.039 | 2.384 | 3.769 | 5.040 | 5.728 | 4.626 | 1.968 | 0.378 | 25.72 |
| 0.555 | 0.714 | 1.765 | 4.013 | 6.449 | 8.543 | 9.806 | 8.042 | 3.375 | 1.117 | 44.38 |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.362 | 0.000 | 0.000 | 0.36 |
| 0.099 | 0.134 | 0.313 | 0.724 | 1.130 | 1.488 | 1.729 | 1.383 | 0.577 | 0.142 | 7.72 |

---

**Is it that big of a difference?**
Constant Power versus Constant Current

<table>
<thead>
<tr>
<th></th>
<th>PSE Power</th>
<th>Cable Loss</th>
<th>Relative Cable Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant Current</td>
<td>14285.4</td>
<td>1368.3</td>
<td>9.6%</td>
</tr>
<tr>
<td>Constant Power</td>
<td>13145.3</td>
<td>256.6</td>
<td>2.0%</td>
</tr>
</tbody>
</table>

- Cable current tables used for guidance have lots of margin. That is because there are several accumulated sources of margin:
  - The tables assume all worst case in parallel
  - No link is actually worst case (and 3 parameters have to be worst)
  - Not all the cables are PoE powered
  - The IEEE PoE PSE power classes have margin
  - Rounding to a single digit

98% of the difference is power NOT in the cable plant. This is a HUGE difference.
To Summarize

- A large installation is used to study actual cable losses
- The actual installation in this presentation shows 2% loss versus the 9.6% calculated from all worst-case parameters
- Many parameters affect PoE cable power loss
- Calculating with all of them at worst case creates an exponential avalanche predicting very high losses
- A constant-power test model produces far more accurate results, compared to constant-current which assumes all worst-case
- Cable thermal testing for PoE needs to transition to a Constant Power testing model to prevent significantly over-margined values

EA Whitepaper

- For further analysis of PoE cable losses, please see the Ethernet Alliance whitepaper “Power over Ethernet - Cable Losses”
Thank You!
Powering over LAN Cable

- UL Fact Finding Investigation
- Safety Concerns
- Example of Safety Margins - LP Cable
Fact Finding Investigation

West Baden Springs Hotel PoE Cabling
500 Lights, 220 Control Nodes
**Fact-Finding Investigation**

**DEFINITION:**

**FACT-FINDING REPORT (INVESTIGATION)**
A formal record of an investigation of the features and properties of a product, assembly or system undertaken by UL for the purpose of providing an Applicant with a means for seeking amendment of a nationally recognized installation code or Standard toward which UL's work is oriented.
Fact-Finding Investigation

PURPOSE:

- Investigate the effects of higher levels of power applied over communications cables under typical installation practices permitted by the NEC
- Support Public Inputs already submitted
- Determination and evaluation of realistic worse-case conditions
- Gather data for the development of comments related to the first revisions to the NEC including:
  - Conductor Amperages
  - Bundle Sizes
  - Installation Practices
- Mitigate safety concerns
- Focus on power (volts, watts, amps), not applications

Fact Finding Study on Cable Heating
Larger Bundles + Higher Currents Produce Excessive Heat

[Graph showing increasing bundle size and current producing excessive heat]
The data shows that overheating does not occur at 0.175 Amperes per Conductor.

The data shows that overheating is not likely to occur at 0.3 Amperes per Conductor 60 watts for cables 24 AWG or larger.
The data shows that under many installation conditions overheating will occur at 0.5 Amperes per Conductor

0.5 Amperes per Conductor
(Approx. 100 Watts, 50 Volts, 4-Pair Powering)

The data shows that under a significant number of installation conditions overheating will occur at 1.0 Amperes per Conductor

1 Ampere per Conductor
(Approx. 200 Watts, 50 Volts, 4-Pair Powering)
A Word on Test Methods
Constant Current vs. Constant Power

**Constant Current Method:**

- The constant current method applies a pre-determined current to all conductors to determine the ampacity of the cables in a bundled configuration.
- The NEC® defines Ampacity as:

**Ampacity.** The maximum current, in amperes, that a conductor can carry continuously under the conditions of use without exceeding its temperature rating.

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**Constant Power Method:**

- With the constant power method the current on the conductors is determined by the source voltage, cable resistance and the amount of power consumed by the powered device.
- The constant power method uses a cable length distribution and specific loads to simulate a typical installation so it closely represents cable heating for installations characterized by the simulation. But only for installations characterized by the simulation.
- The constant power method is useful for engineered systems where ampacities are permitted to be “determined by qualified personnel under engineering supervision.”
- The constant power method does not produce data that can be used to determine cable ampacities.

*NEC® Table 725.144 Note 4*
Safety Concerns

- Power levels have been steadily increasing
- Power levels and power density will continue to increase
- Cables are often installed in bundles
- Bundles result in a cumulative heating effect
- Heat is trapped
- Cables (especially at the center of the bundle) can overheat
- Safety and performance can be compromised
## Permitted by Table 11(B) Class 2 and Class 3 Direct-Current Power Source Limitations

### Table 11(B) Class 2 and Class 3 Direct-Current Power Source Limitations

<table>
<thead>
<tr>
<th>Power Source</th>
<th>Class 2: Inherently Limited Power Source (Overcurrent Protection Not Required)</th>
<th>Class 3: Not Inherently Limited Power Source (Overcurrent Protection Required)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source voltage $V_{max}$ (volts) (see Note 1)</td>
<td>0 through 20°</td>
<td>Over 20 and through 30°</td>
</tr>
<tr>
<td>Power limitations $V_{max}$ (volts-ampere) (see Note 1)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Current limitations $I_{max}$ (ampere) (see Note 1)</td>
<td>8.0</td>
<td>8.0</td>
</tr>
<tr>
<td>Maximum overcurrent protection (ampere) (see Note 1)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Power source maximum nameplate rating</td>
<td>$V_{max}$ (volts-ampere)</td>
<td>5.0 $V_{max}$</td>
</tr>
<tr>
<td>Current (ampere)</td>
<td>5.0</td>
<td>$100V_{max}$</td>
</tr>
</tbody>
</table>

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### Permitted by Table 11(B) Class 2 and Class 3 Direct-Current Power Source Limitations

**Cat 5e, 24 AWG, 7-Cable Bundle**

3.0 Amperes per Conductor

Open Air
Permitted by Table 11(B)
Class 2 and Class 3 Direct-Current
Power Source Limitations

![Graph showing cable temperature and current limitation]

Cat 6 CMP 23 AWG, 192 Cable Bundle
in Closed Cable Routing Assembly
1 Ampere per Conductor

Multiple Class 2 Circuits in a Cable

725.139 Installation of Conductors of Different Circuits in the
Same Cable, Enclosure, Cable Tray, Raceway, or Cable Routing
Assembly.

(A) Two or More Class 2 Circuits. Conductors of two or more
Class 2 circuits shall be permitted within the same cable, enclosure,
raceway, or cable routing assembly.
Multiple Class 2 Circuits in a Cable

Permitted by 725.139(A)

Conductors of two or more Class 2 circuits shall be permitted within the same cable.
1-Pair Power over Data Lines (PoDL)

- Sheath Sharing = Four independent single pair applications are run over a four pair cabling system

The data shows that under a significant number of installation conditions overheating will occur at 1.0 Amperes per Conductor

1 Ampere per Conductor
(Approx. 200 Watts, 50 Volts, 4-Pair Powering)
Permitted by Table 11(B)
Class 2 and Class 3 Direct-Current
Power Source Limitations

Cat 6 CMP 23 AWG, 192 Cable Bundle
in Closed Cable Routing Assembly
1 Ampere per Conductor

CMP, 23 AWG, 90C, Cat 6, White
192 Cable Bundle in 5” Schedule 40 PVC Conduit
1 Ampere per Conductor
187 Degrees C
Example of Safety Margins - LP Cable

What is an “-LP” Cable

- Developed by UL at the request of the W&C industry
- Based on the knowledge gained from the fact-finding investigation
  - Data showed that cable heating can be managed via:
    - Increased AWG size
    - Cable design Variations
    - Material selection
    - Installation Practices
- Takes advantage of innovative cable designs
- Is not dependent on the installation
- Simplifies the planning and installation process (no bundle restrictions)
"-LP" Cable Safety Factors

- Safety factors
  - 192 cable
  - Tightly packed bundle
  - All conductors carrying current
  - In conduit
  - Insulated ends
  - +20°C offset

-LP Criteria

+20°C Offset
“-LP” Cable

- An additional, optional rating that may be added to traditional cables like “CL2”, “CMR”, “CMP”
- An alternative to the ampacity table
- Not required for new or legacy installations
- Permits taking advantage of cable design and construction innovations