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THE MAGAZINE OF ELECTRICAL DESIGN, CONSTRUCTION & MAINTENANCE ®

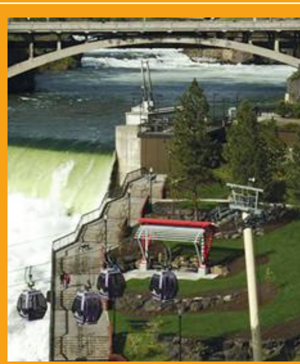
LEDs STILL A MYSTERY?

As LEDs flood the market, contractors must balance the appeal of online buying with the need to grasp a technology still shrouded in uncertainty.

FORENSICS

Whodunnit? Multiple theories examined before real culprit is identified

LIGHTING DESIGN



Haste makes waste: Don't speed through those lighting circuit voltage drop calculations

CODE BASICS

Burn prevention: Size your conductors so they won't melt

LIGHTING & CONTROL

Future forecast: Chips, sensors, and controllers are agents of change

ILLUSTRATED CATASTROPHES

Hickory, dickory, clock: This rhyme doesn't end well

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DENALI HD

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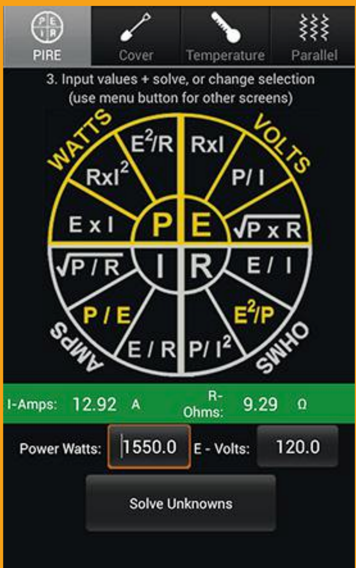

8 GREAT ELECTRICAL APPS: PART 3

Photo Gallery ▶ These mobile apps are designed specifically for electrical designers and installers.
http://bit.ly/1BmSov2

SENSITIVE ELECTRONIC GROUNDING IN INDUSTRIAL LOCATIONS

IdeaXchange ▶ Learn why isolated grounding electrode systems are not acceptable.

BECHTEL TO EXPAND PRESENCE IN FAIRFAX COUNTY

News ▶ Engineering firm to relocate 700 employees and invest $10 million as a result of this move.
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ONLY ON THE WEB

WHAT'S IN THE NEWS?

Electrical Workers Shocked at King of Prussia Mall

One of two workers hurt in an electrical accident April 13 at the King of Prussia Mall in Pennsylvania has died. The construction workers were injured while working from a scissor jack lift.

http://bit.ly/1CWJ51q

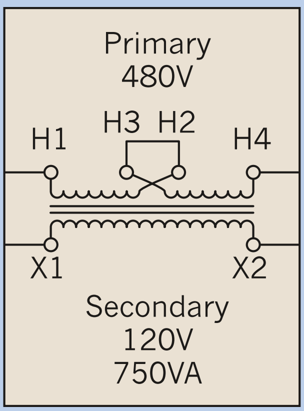
Postal Service Cited for Electrical Hazards at Chicago Distribution Center

OSHA found workers at a Chicago Postal Service Distribution Center were exposed to various electrical hazards and issued two repeat, four serious, and one other-than-serious violation with proposed penalties of $63,540.

http://bit.ly/1FRsD6O

EDITOR'S CORRECTION

The figure that appeared in the February and March Tech Training articles, "Troubleshooting Motor Control Circuits – Parts 1 & 2," contained an error. As seen in the corrected image here, the jumper on the primary side of the control power transformer should be placed between H2 and H3 for a 480V supply.



WHAT'S NEW?

Riding in Style: 10 Great Vintage Work Vehicles

Photo gallery ▶ Who knew vehicles of yesteryear displayed such ingenuity and downright charm? To show our appreciation, we've put together a gallery of some of our favorite work automobiles from years gone by.

http://bit.ly/1asz8l9

WHAT'S POPULAR?

Top 10 Highest Paying Cities for Electricians

Photo gallery ▶ If you're an electrician looking for the highest possible pay in the nation, then California is definitely the place to be. Don't live in California? No worries. Click through our photo gallery to find out if your city is one that pays electricians the big bucks.

http://bit.ly/1DZrmeK

WHAT'S BEING SHARED?

Moving Violations Video No. 93: Missing Guard Strips

In this episode, Russ finds some unprotected NM cable in an accessible attic space. Sections 320.23 and 334.23 of the 2014 NEC require cables installed in this space to be protected with guard strips.

http://bit.ly/1FRqRT6

The Strange and Mysterious World of LEDs

By Michael Eby, Editor-in-Chief

One thing has become quite clear to me recently. There's still a lot of confusion out there on the LED front among the rank and file of electrical designers, maintenance personnel, and electrical contractors. And it seems to be getting worse the more this technology evolves. In the beginning, the questions were somewhat basic. How long will these lamps last? What's the basic technology behind their operation? How much energy do they use? Where can I install them? How do I justify their high initial cost? Because early generations of this product line took on the form factor of existing lamps, there were also questions and concerns about light output — mainly as viewed by the customer. Quality of light was a big concern, but most everyone seemed to move on from these issues after a reasonable amount of time.

Then the questions quickly shifted to dimming and control and driver compatibility concerns. Why can't I control new LED lamps with my existing dimmers? Do you really expect me to test product compatibility on my end through mock-up test installations? How do I future-proof my installations so I don't have to change out the entire system when individual components start to fail?

But before the masses could even begin to feel comfortable about these issues, the rapid development of this technology is now giving manufacturers the flexibility to create new mechanical and optical designs never seen before. It's no wonder the engineers and contractors that are trying to incorporate LED luminaires in their electrical design plans are scratching their heads a bit these days. And so are the maintenance professionals charged with servicing and replacing these new luminaires.

Our cover story this month, "LEDs Still a Mystery to Many Contractors," touches upon a few of these technical issues, but mainly sheds some light on an entirely different topic — the purchasing component of an LED lighting system installation. As we all know, the Internet offers a quick and simple point of entry for new manufacturers and suppliers. That's not a bad thing, but it opens the door for those interested in supplying cheap and unproven products into the market. It also makes it much more difficult for a buyer to assess quality and compare specs from various suppliers.

But purchasing problems aren't specific to the online world. Contractors are also struggling to get the technical information they need from their traditional local electrical distributors. When they don't get the service they feel they deserve from their trusted local distributor, they are forced to take matters back into their own hands — and that means heading right back to the Internet in search of answers.

One of the key points made in this article is that buyers must match the right product to the application at hand and make sure they can rely on the supplier for future service and support — no matter what type of product you're buying. In other words, when buying online, it's important to be extremely cautious.

Dumb lighting systems are a dying breed. Success on the LED lighting front will be based on smart product purchases and technical proficiency in the areas of network control systems, sensors, digital interfaces, software, and building automation systems. If you don't keep pace with this new technology and make smart purchasing decisions, then you just might disappear too.

The Case of the VFD Clock Culprit

Forensic engineers eliminate multiple theories behind the death of technician troubleshooting a factory air compressor, ultimately discovering one unlikely wiring arrangement was to blame.

By Sarosh H. Patel, Ph.D., and Lawrence V. Hmurcik, P.E., Ph.D., Lawrence V. Hmurcik, LLC

The day started out like any other for one electrical technician employed by a variable-frequency drive (VFD) manufacturer. He went to work as usual, resuming a service call at a factory where he'd been working as a subcontractor all week troubleshooting an air compressor, which included a VFD to control its speed, that had been put out of service by a lightning strike. Tragically, the work day was cut short when an employee found him lying on the floor close to the panel with a head wound and not breathing. Following the accident, forensic engineers contemplated many theories — ruling them out one by one — before determining what caused the electrocution that ultimately took the life of this unsuspecting technician.

The scene. Unbeknownst to the victim, prior modifications had been made to the circuitry that controlled the compressor. Earlier, a contracted electrician had performed a "changeover" that altered the internal wiring of the air compressor so it would either be run on direct line power (480V, 3-phase, 125A per phase) or through the VFD. This work was followed up by the factory's own electrician, who also made a modification. He "improved" the electronic clock by using the 60-Hz frequency of the line voltage to synchronize it by tapping into one of the three 480V legs of the input power. Because the current drawn by the clock was approximately 25mA, this did not cause an imbalance in the 3-phase circuit — but it did have another consequence, which will be revealed later in the article.

The accident. On the morning of the accident, the technician checked into the facility and continued working on the system, just as he'd done every day for the past week (**Photo 1**). A few hours later, an employee found him lying unconscious on the floor close to the panel in front of the circuit he was working on with tools next to him. The employee immediately called for emergency personnel. Upon arrival, paramedics pronounced the victim dead at the scene.

Photo 1. The open electric cabinet with three phase conductors feeding in from the floor. Plastic acrylic block is opened to expose three fuses limited to 125A per phase. Left of fuses is the clock wire that bypasses the safety interlock. In the top of the picture is the beginning electronics of the VFD.

The employee told police he had pulled the victim away from the electrical circuitry as soon as he found him. In addition, the police report and witness statements all described the victim as appearing "deep purple" in color — a gruesome detail but one that nonetheless would prove to be crucial for investigators to uncover the underlying cause of his death.

Another important observation related to the large metal frame (approximately 6 in. × 6 in. × 2 ft), which contained a bank of capacitors charged to 500V and was sitting on the floor next to the VFD. It had obviously been un-screwed from the rack that held the VFD (**Photo 2** on page 12). Following the accident, the factory's full-time electrician immediately opened the main breaker, which was still energized, and pulled out two fuses to deactivate the panel the technician had been working on. At that point, he also notified OSHA of the accident.

The lawsuit. The plaintiff in this case was the widow of the deceased technician. We were hired by the plaintiff's attorney as forensic experts to determine if the accident scene was unsafe (according to normal electrical procedures) and if negligence (on the part of the company and the company's electrician) was responsible for the victim's death.

The investigation. We made two site visits, each time taking measurements and photos of the suspect cabinet and capacitor bank. OSHA had performed its site investigation prior to this visit. We had access to a police report, autopsy report, second autopsy report (performed at the plaintiff's expense), OSHA report with photos, report from two cardiologists (hired by plaintiff's attorney), and reports

from several experts hired by the defendant. Considering how much evidence was available — coupled with the fact that there were so many potential electrical "suspects" — this case was somewhat unusual. Basically, any of the following suspects could have killed the technician:

1) A back-EMF from the VFD
2) An exposed 480V line
3) The capacitor bank
4) A hot circuit or sub-circuit in the electrical cabinet.

Forensic analysis. Based on the investigation, we gathered many facts relating to the electrical arrangement that helped reconstruct possible scenarios leading up to the accident. Coming up from the floor at the electric cabinet was a large diameter conduit that contained four wires — one grounded conductor and three ungrounded conductors. The circuit was rated 480V and connected in a 3-phase star arrangement. The ungrounded conductors were connected to a terminal strip block at the bottom of the cabinet. The entire block was covered with a large acrylic plastic block, and the door was designed with an automatic shutoff.

The top of the terminal block was easily accessible, but it was automatically disconnected when the door opened. Although the bottom of the terminal strip remained live at all times, to reach it, a person would have had to kneel on the floor and reach under the plastic in a fashion most people would find extremely awkward or even impossible.

The capacitor bank consisted of a metal base upon which six electrolytic capacitors (rated at 500V and 15,000 μF) were found. All capacitors had one lead tied to the metal base. Therefore, the base was a "chassis" ground, which is designed to be mounted on the metal rack with screws. When it is screwed in place, the chassis ground becomes an earth ground because the rack has a direct connection to earth.

The electric cabinet supplied a VFD connected to a very large 75-hp motor. The VFD required a clock to synchronize its output frequency (i.e., chopping frequency). The clock required a trivial amount of current to operate. The frequency of choice by the manufacturer is 60 Hz, since this is readily available from the line voltage found in most U.S. electrical systems. Using 60 Hz as a standard, many other frequencies can be generated via routine logic circuits.

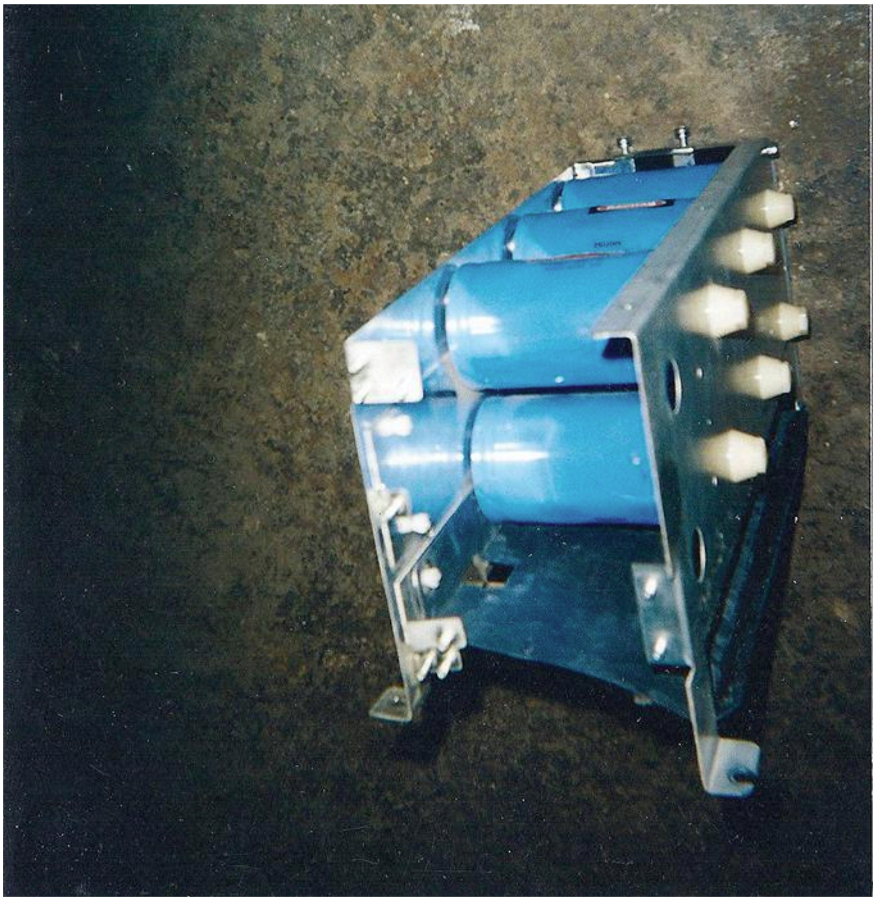


Photo 2. Capacitor bank lies on floor next to open electric cabinet. "Hot" lead of each capacitor is protected by a plastic cap (on top of the aluminum metal housing). "Cold" lead of each cap is tied to aluminum housing as a chassis ground.

From the output power of the 3-phase circuit, a single thin wire ran from one of the phases (where it made electrical contact) through a limiting resistor and to the clock. Because each phase supplied 125A — and the draw from the clock chip was limited to 25mA — there was no concern about mismatching the one phase relative to the other two. In fact, to ensure stability, a wire was run by the company electrician from the point where the input conduit came in from the floor beneath the electric cabinet. The wire tied into one of the three phases, and then went directly through the limiter and to the clock chip.

A lockout/tagout procedure governs the electric cabinet. Overhead (on the ceiling) was a disconnect that could limit all power to the electric cabinet as well as the VFD and motor (**Photo 3** on page 14). The problem was this disconnect was located 25 ft away from the VFD control rack and accessible only by a ladder or pole. However, if the overhead disconnect was ON and someone opened the electric cabinet's door, then the input power from the conductor running through the conduit at the bottom of the cabinet was cut off from reaching the top of the cabinet. This feature is an automatic shutoff built into the VFD by the manufacturer.

Cause of death. Death by electrocution can occur in a variety of ways, but the most common are asphyxiation and ventricular fibrillation (VFIB). In the former, a person's heart keeps pumping, but since he or she has exceeded the let-go current, the lungs are not able to breathe in and out. Therefore, in approximately 3 min., the victim suffocates (i.e., asphyxiation).

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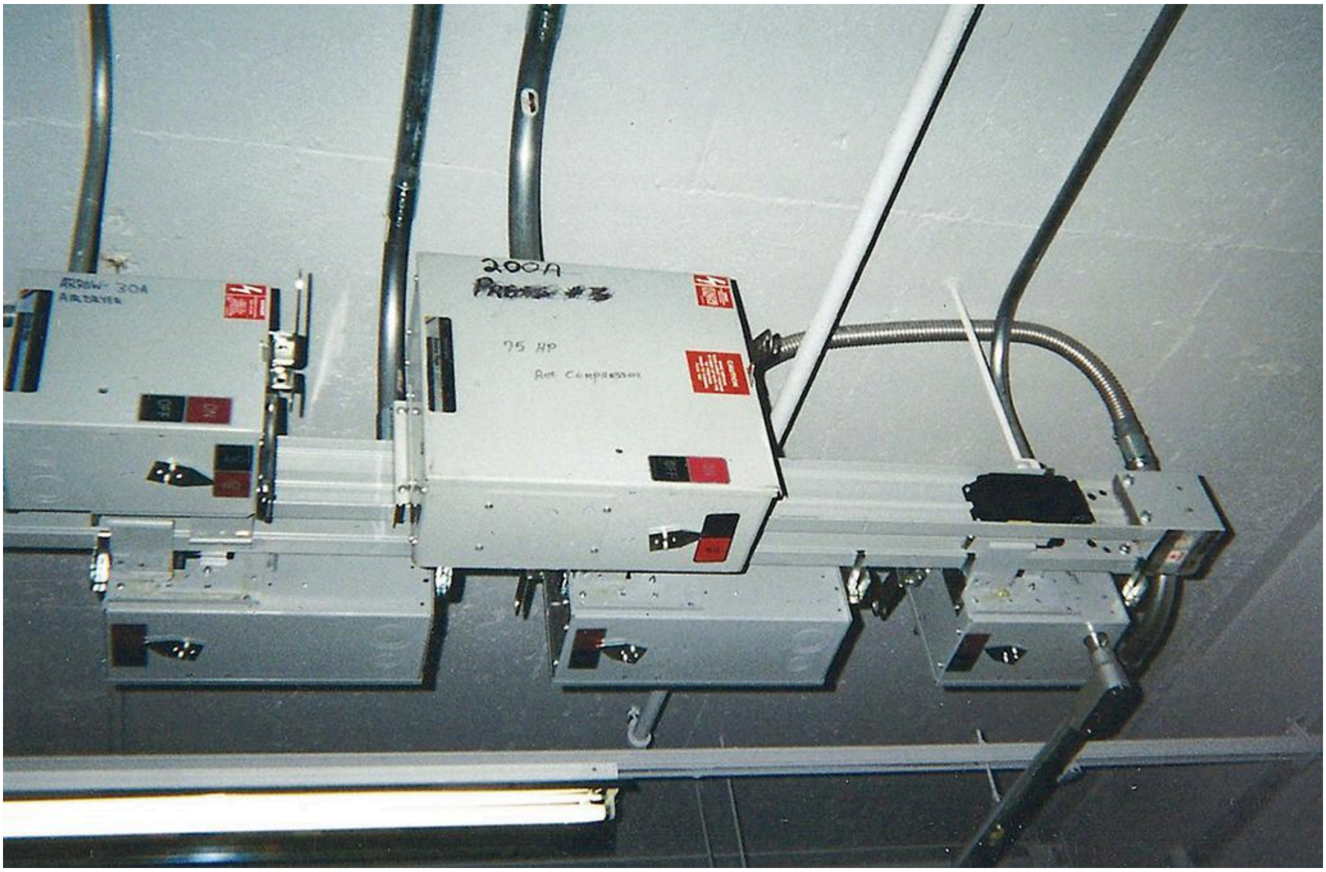

Photo 3. This overhead safety switch is connected to the VFD. It is located too far away to be of any advantage in this accident.

Immediate death (within seconds) occurs due to VFIB, apnea (respiratory arrest), and secondary trauma. In this case, no findings in the autopsy report were consistent with blunt trauma, hence secondary trauma was ruled out as a possible cause of death (despite the victim's head wound).

Because the technician appeared deeply cyanotic (purple), his heart most likely continued to function normally for nearly 3 min. (or possibly longer) while his lungs failed. This is also supported by the coroner's report that mentions "dark blue fluid" found in his lungs.

The culprit. With the cause of death attributed to asphyxia, we looked for the source of electrical energy and the current flow geometry responsible for the victim's death. The lesions on his left hand were consistent with electrical injury — both on a macro and micro scale. The burn marks were clearly visible, even to the non-medical eyes of witnesses and police. In addition to the shock value of the electric current, we needed to consider the entry and exit points as well as the geometry of the current flow. Finding out the exact cause of the death was important not only for closure to this sad case, but also because we needed to figure out who was genuinely responsible for the victim's death — and consequently who should make payment to his wife and family. We considered the following scenarios:

Was it the line voltage?

Did the technician accidentally come in contact with the line voltage? Suppose he reached under the plastic acrylic plate with one hand while touching the metal cabinet frame (ground) with the other. Although this was a very difficult maneuver, we needed to rule this out. In this situation, the technician would have been touching 480V line voltage, which is certainly enough to kill him. Current would be well over the 100mA needed to produce VFIB. We ruled this out as the cause of death.

An alternative theory was that the electrical path could be from the point of contact with the left hand touching the line voltage and then going to the victim's feet. This led to two different scenarios. If his shoes conducted well (maybe they were worn out and filled with sweat), then the victim would die of VFIB, because the 480Vs would push a great deal of current. But what if the shoes acted as insulators? If so, how much insulation did they provide?

As part of this study, we tested the victim's shoes, and the resistance was found to be 6 to 7 million ohms. We did not rely on a simple multimeter to find this value. Instead, we hooked up a 480VAC RMS power supply to a "dummy" foot, which was weighted to half the victim's weight. The dummy foot was conductive, and we added a layer of conducting cream to the bottom of the foot — where it touched the inside of the safety shoe worn by the victim. The shoe-foot rested on a grounded metal plate. The variation of 6 to 7 million ohms was found as we moved the dummy foot from side to side to simulate normal human motion. The maximum current measured in our test was 60 µA — certainly not enough to cause even minor discomfort.

For the sake of achieving certainty in our results, we ran a human test as well. A human wearing one of the deceased's safety shoes with conductive cream inside had a 480V source applied to the lower leg for several minutes. A current interrupt circuit was also placed in series with the human to ensure no possible injury. The results were as predicted: Nothing happened. The maximum current was less than 50 µA, but there was a great variability in the exact value of this current as the subject moved slightly. We concluded that the feet/safety shoes were not part of the circuit that led to the technician's death. Therefore, we concluded contact with the line voltage did not kill him.

Was it the capacitor bank?

It is significant that the only thing the technician removed from the electric cabinet before he died was the capacitor bank, which was sitting on the floor next to him. If the capacitor bank killed the victim, then the electric current would not be constant — it would be diminishing in an exponential fashion. Yet, if it remained large enough for a long enough period of time, it could be the cause of death.

The capacitor bank was actually a prime suspect. Assuming a human to have approximately 1,000 ohms of resistance, the peak current would be 500mA. But when a resistance is attached to a capacitor, the current drawn decays to zero over time. However, was the current enough to kill the technician during the time he held it? Also, would it kill via VFIB or asphyxiation? We answered this question based on evidence from the scene.

If the technician were holding the capacitor bank when it began to jolt him, he would fall, which would break the circuit. There was no evident damage to the capacitor bank's frame from it being dropped, and all capacitors appeared to be close to fully charged when we measured the voltage across each. Similarly, if the bank was resting on the floor — and if the technician bent over and touched one of the hot leads — he would also have to touch the metal base with his other hand (not a very likely scenario). So, even if the capacitor bank could have killed the technician, the ancillary evidence did not support this theory as the mode of death. Therefore, we concluded the capacitor bank did not kill the technician.

Was it the motor's back-EMF?

We measured the back-EMF from the motor — it exceeded 10,000V, but it lasted less than a second (approximately 50 to 100 msec). The back-EMF from the motor is caused when the motor is brought to a sudden stop — the mechanical energy of the spinning motor is fed back to the input circuitry. However, the back-EMF was not a very good suspect. Granted, there was sufficient power, but the voltage decayed so quickly that it could not have killed the technician in the manner of asphyxia.

In order to turn the motor on and off, a sequence of events must take place with the door of the electric cabinet closed. Once opened, the door automatically disconnected the line power, and any voltage/power in the motor was subject to a rapid decay. How could the technician open the door in the usual manner, remove the capacitor bank, and do all this in less than 1 sec? The bottom line is back-EMF is deadly over a very short interval. The human must already be in harm's way when the back-EMF begins. Any delays can result in the human escaping harm. Add to this the fact that the autopsy pointed to a long death (3 min.). If the back-EMF were to have any effect on the technician, it would have had to kill him over the very short time that it had sufficient voltage to do so. Therefore, we concluded that the motor's back-EMF did not kill the technician.

Was it the junction box?

There was a junction box located on the wall near the VFD, which was installed with the purpose of controlling the electrical architecture of the VFD arrangement. If it is wired in one mode, then the VFD operates as the manufacturer intended — line voltage goes into the bottom of the VFD and leaves/enters the air compressor. This is a series connection. In the second mode, the air compressor can operate independent of the VFD. The junction box mounted on the wall next to the VFD had no role in this accident — all attempts to find an electrical leakage at the site failed. The box was wired properly; therefore, the junction box did not kill the technician.

Was it the VFD clock wiring?

As noted earlier, a grey fuse box was powered even when the VFD disconnect was in the OFF position. Furthermore, there was still one wire leaving the grey fuse box and traveling up to service a portion of the VFD (i.e., the clock circuit). The important thing is that the VFD (or a portion of it) was powered even when the VFD was supposed to be de-energized due to the disconnect being in the OFF position. Furthermore, the VFD was powered in a fashion that would moderate the levels of current to those low values enough to cause asphyxia and cyanosis. The actual components that reduced the current flow are many, but the primary ones are: the fuses, control relays, control transformer, and circuit board controlling the VFD. The current from this "hot" wire was limited to 25mA, according to tests by multiple investigators in this case.

The grey fuse box bypassed the safety feature of the VFD-disconnect. Power was supplied to the VFD clock even when the disconnect shut the main power off.

The grey box was current limited to 25mA, which is sufficient to exceed the let-go current and kill via asphyxiation. Hence, we concluded that it was the only thing that could have killed the technician.

Ironically, the part of the VFD setup that had the lowest current and power killed the victim. It had not been subjected to the scrutiny reserved for the high power components. It did not have a lock-out, tag-out protocol that an ordinary technician could use. There was a master disconnect to the VFD, but it was on the ceiling 25 ft away.

The disconnect (on the ceiling) was placed into the OFF position the previous day — the company electrician did this in front of the technician. To do this, the electrician obtained a ladder and climbed up to reach the switch. The next morning, the electrician re-energized the circuit by turning this switch back on before the technician arrived as a favor to help him get a quick start on testing. Apparently, the electrician also had to run off and do other important jobs at the company, and could not wait for the technician that morning.

The technician began his work with the electrical cabinet "live." The safety features built into the cabinet (we found) were sufficient to protect the technician from all dangers due to the major power being fed to the VFD, once he opened the door. But the clock circuit bypassed the "turn-off" switch of the cabinet door, and this remained energized when the accident scene was investigated.

The outcome. Based on the forensic investigation and analysis, we determined the company was responsible for the technician's death. Its representative (a licensed electrician) bypassed a necessary safety feature on the VFD unit in order to power the clock circuit. In addition, the only "safety disconnect" switch was located 25 ft away from the VFD and accessible only by a ladder. The technician knew the power to the VFD was shut off on the evening before. He could have assumed it to be shut off the next morning. The technician may have checked all line voltages leading into the VFD with the door open. If so, he would have found all voltages to be zero. The small clock wire was easy to miss on a cursory scan of the unit by a non-electrician. Ultimately, the technician was fully capable of servicing the VFD as it was designed. Furthermore, with the help of the company's electrician, he could have analyzed the added features in a safe manner. However, he was not capable of servicing it based on the safety violations he was not aware of.

Following is the most likely scenario that occurred on the day of this tragic accident. The technician opened the cabinet. He checked the line voltages (480V per phase when ON), and found the voltages to be zero. Hence, he assumed the power to be off. He may have had the fan motor running. But when he opened the electric cabinet, this went quiet rapidly — and any back-EMF disappeared quickly as well. He removed the capacitor bank safely. He might have performed several other tests safely. Then he probably touched a portion of the clock circuit or the wire running to it with his right hand, while his left hand rested on the metal frame of the cabinet (electric ground). At this point, his 3 min. of asphyxiation had begun.

This case was set for trial, but shortly after our report was issued, the case settled. The company accepted no blame for any wrongdoing; however, it did pay the plaintiff a sum of money. The electrician working for the company was never charged or sued. A secrecy agreement precluded anyone but the company management and the plaintiff from knowing the exact amount of money paid out. No lawsuit was brought against the manufacturer of the VFD or the service company that employed the technician. **EC&M**

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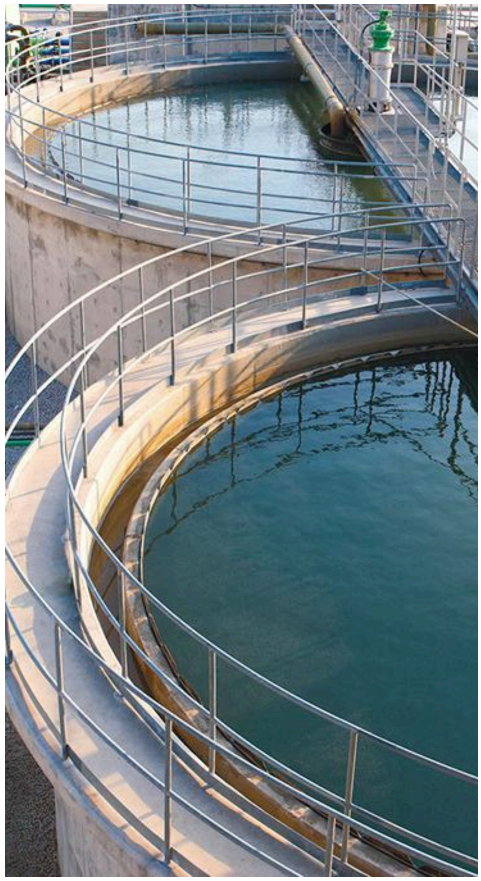
Water Supply and Sewage/Wastewater Disposal

Information provided by FMI, Raleigh, N.C.

Water supply construction fell 5% in 2014, and FMI expects it to grow just 1% — to $13.0 billion — in 2015. The good news for sewage and waste disposal construction is that modest growth of 3% to 4% is expected for the same forecast period. This is an improvement over the last few leaner years, and growth may be aided in some industrial areas with a growing manufacturing sector. As in other areas of public infrastructure, the need for improvements in water supply is great, but the investment is lean.

"In today's market, there is arguably no sector facing a more critical shortfall between demand and investment than the U.S. water market," says Gregg Powell, vice president of FMI.

Government spending has been limited. Federal assistance for the safe drinking water State Revolving Fund (SRF) in the 11-year period between 1997 and 2008 totaled $9.5 billion, just slightly more than the investment gap for each of those years. In recent years, the Clean Water State Revolving Fund (CWSRF) programs have provided more than $5 billion annually to fund water-quality protection projects. The drought crisis in California will



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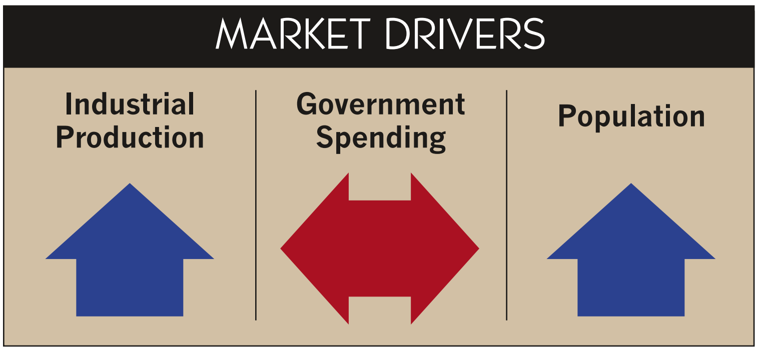
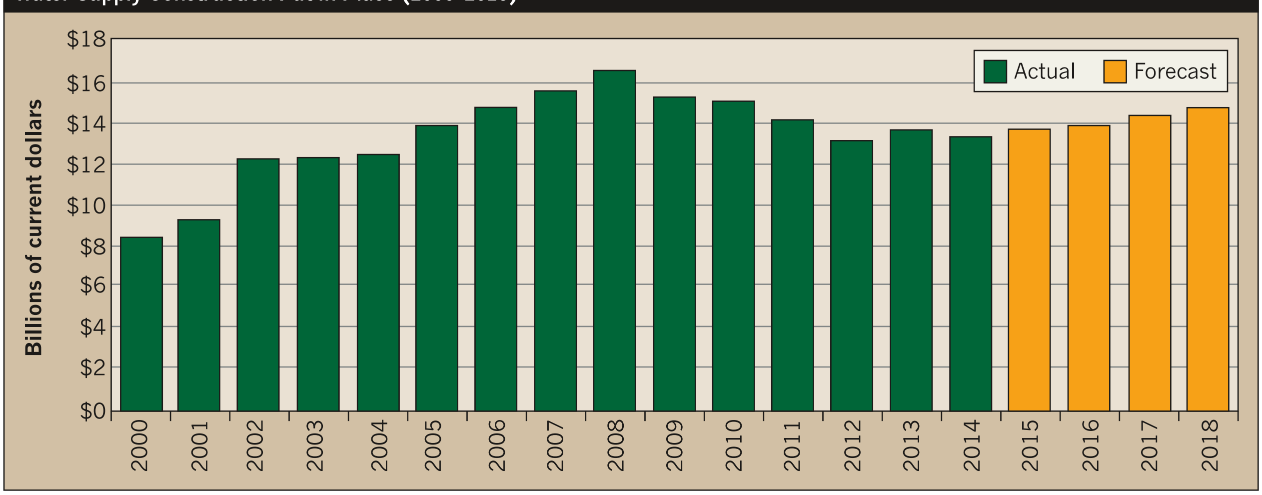


Water Supply Construction Put in Place (2000-2018)



Forecast as of first quarter 2015.

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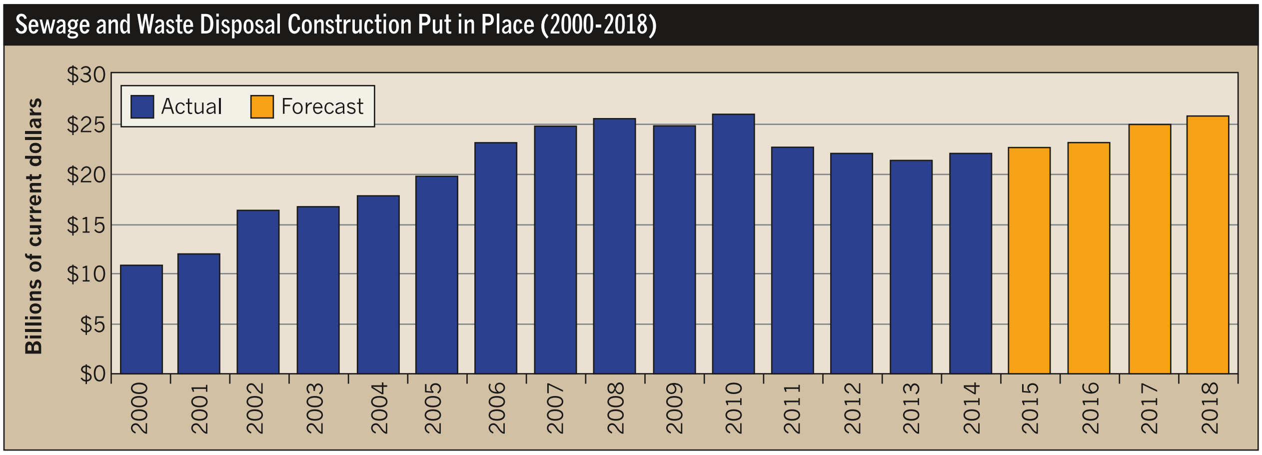

Forecast as of first quarter 2015.

be instructive for the rest of the nation, as the state will have to increase spending on water resources.

"The country's water and wastewater infrastructure suffers from subpar conditions throughout the supply chain, encompassing water intake, diversion, transportation, storage, treatment, and delivery," notes Powell.

Nonetheless, these key sectors will continue to compete with other infrastructure sectors for public funds. **EC&M**

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Building and Empowering Your Team

A team approach is what really drives a successful residential service business.

By Bill Murdy, Mister Sparky

"What is the one thing I need to do to build a successful residential service business?" I'd like the proverbial nickel for every time I've heard that one. Can I break it down to performing one function that will ensure the success of my service business? If I did, would it be recruiting? Maybe training or possibly marketing? What is that silver bullet that will solve all of my problems?

It's human nature to look for the easy way out. We all do it, but is it realistic to believe we can accomplish one task at the expense of all others and get the results we need? I think you know where I'm headed here. Business, and, in particular, residential service, has a multitude of moving parts that all have to be coordinated so the machine will operate properly.

As owners or general managers, you are the conductors. To get to where you are, you had to bring a team together, spend time to train them, and then manage them to see your goals achieved. If there is a "silver bullet," it's you! You've got the vision for where you want to go, and you have to share that vision with your team and get their buy-in. You can't do just one thing to see your company grow, and you can't do it all yourself. Deep down you know that, but it's difficult. You need to create a culture of teamwork so that your team can see their individual success growing with the goals of the company.

As you grow your company, it becomes more important that other employees take over some of your roles. Do a little soul searching, and find out if you're the "funnel" in your own business. Do you get back to the office and have a list of people you need to call back at the end of the day?

Bill Murdy

Could someone else have handled some of these calls? Were they all really that important? Empower your employees to make decisions, create the growth plan with them, and you'll all share in the benefits of better teamwork.

How do you accomplish this? Create performance goals and track them. Remember, you can't improve what you don't measure. Get a performance baseline, and find out how you're doing now.

For your customer service reps, check your closing percentage. Discuss with the team the challenges that are being faced, and establish a plan for improvement. Seek their input, and work with them to get their buy-in. Are they handling the challenging calls or just passing them on? Coach them to explore solutions with the customers themselves. Do you have inspections or service agreements that need to be scheduled or some other form of outbound calling to keep the guys busy during slower times of the year? Create the script, and track the results. Remember, incremental improvement is a win for all. Celebrate the gains, and post the results.

Look at the areas that need improvement in your service techs. Closing percentages are very important here as well. Do you have a star among you that is outperforming everyone else? Explore that employee's process in your training meetings and allow him or her to mentor the newer techs. How are your material percentages on your job costing? Can you work with your techs to establish a better system for procuring material and getting returns credited?

Whatever you're measuring, work with the team so that you'll get their buy-in. Track the results, and once the baseline is established, look for improvement. But make it realistic, and set time deadlines to hold yourself and your team accountable. You'll find yourself establishing systems that will streamline the way things are done and enable your team to handle any challenge.

As your company truly becomes a team, you'll find that you're no longer "putting out fires." Your time can be spent steering your company toward the vision you've shared, and you're no longer the only one rowing the boat. **EC&M**

Murdy grew up in the electrical industry and holds a degree in electrical engineering. He has been in the residential electrical service industry for 30 years and has been a business owner for more than 25 years. He independently owns and operates the Mister Sparky electric franchise serving western Long Island, N.Y. He can be reached at bill.murdy@mistersparky.com.

A Look at the Future of Lighting

By staying on top of trends in energy efficiency, safety, and the visual environment, electrical contractors can gain new business and improve lighting quality in the process.

By Joe Knisley, Senior Editorial Consultant

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The lighting industry is in the midst of a major transformation, resulting from the U.S. government's push for energy savings. Because lighting accounts for between 20% to 40% of a building's electrical load, regulators constantly want improved lighting energy performance. Therefore, lighting is becoming a proactive agent of change as we learn more about spectral distribution, the physics of color, the physiology of vision, and the relationship between light and health.

Reviewing some of the developments seen in the aisles at the 2014 Lightfair International show gives us an idea of what lies ahead. Here are three major lighting trends you should know about:

Solid-state illumination will dominate new growth. The LED light source is not the only game in town, but it sure is capturing all of the attention right now. It opens the door for a whole new presentation of what electrical illumination can, and will, do for us. Last year, for the first time since 1911 — when the Illuminating Engineering Society Progress Committee was formed — no luminaires using incandescent, fluorescent, or HID sources were named in the 2014 IES Progress Report, which showcases products that provide significant technical advancement in the art and science of lighting.

This means that with the LED chip continually improving in efficacy, longevity, and cost, the general lighting market in commercial, institutional, and industrial projects will eventually shift to solid-state lighting in some form or another.

The organic LED (OLED) source is a complementary technology experiencing gains in performance and reductions in cost. An OLED consists of stacked organic (carbon-based) thin films sandwiched between two current-carrying electrodes, which are typically enclosed in plastic or glass, providing diffused light with little glare. These panels have a source brightness ranging from 2,000 to 6,500 candelas per square meter, and the output can be monochromatic (single color) or it can be color tunable using a red, blue, and green source mix. An OLED panel can integrate with architectural materials and surfaces, such as walls, ceilings, or furniture, and efficiencies are expected to breach 80 lm/W. However, until there is a significant change in the vacuum thermal evaporation (VTE) manufacturing process (a slow and expensive method), the OLED source will remain expensive for general illumination.

Other solid-state lighting technologies, such as glowing graphene sheets, may develop and partner with LEDs for specific lighting applications. In general, however, as solid-state lighting continues to develop, code-mandated lighting power densities will also likely decrease.

Connected and responsive lighting will offer unprecedented control. Architects, building owners, and users, along with lighting designers and electrical engineers, understand that the LED source is inherently controllable through its driver. And digital technology can offer better data input, conversion, and application scenarios than ever before, since the processing power of a PC has been shrinking and finding a home within a tiny chip in both luminaires and lamps. Sensors

Move to More Stringent Building Codes

Look for building codes to continuously become more restrictive. One of the nation's top three building energy codes and standards — ANSI/ASHRAE/IES Standard 90.1 — 2013, Part 6 of Title 24 of the California Code of Regulations, and the International Energy Conservation Code (IECC) — are generally used by individual states as a reference model. For example, the ASHRAE 90.1-2013 standard has daylighting design criterial along with daylighting controls and space-by-space power densities. The California Title 24-2013 rules have lowered compliance thresholds significantly, meaning that even modest retrofits or lighting upgrades may trigger code compliance for basic requirements, such as automatic lighting shutoff. The codes are also becoming increasingly performance-based. For instance, the latest version of the IECC includes an additional performance-based pathway, which is already popular in many states.

embedded in luminaires can gather data not only from photocells and proximity/occupancy detectors, but also determine carbon dioxide and sound energy levels (among other parameters) using low-power microprocessors. Overhead luminaires can recognize when a specific person is working in an office and customize the surrounding lighting scene. The same luminaires can be programmed to provide constant light and color output over their rated life, thus achieving longer service life and consistent white color temperature.

Other trends to note regarding luminaires for general lighting include: the wide range of color temperatures offered both as adjustable CCT and warm dimming options; drivers that use multiple dimming protocols; control features with self-commissioning and remote control configurations; and controls that stress code requirements rather that actively managing energy consumption. In addition, the industry has its first solid-state dimming standard, NEMA 7A- 2013, which addresses the incompatibility of some dimmers and LED luminaires with the goal of achieving better performance and reliability.

While onboard analog control sensors first appeared in linear fluorescent fixtures years ago, today's digitally addressable fixtures offer a more granular degree of control and flexibility for a variety of components attached to a network. For example, an emerging control capability is having LED lighting communicate messages and provide way-finding at retail facilities and other locations. Retailers can now set up a visual light communication (VLC) system, which involves modulating the output of the overhead LED lighting system to create a coded signal (rapid light pulses) that can be received and detected by the customers' cell phone camera. The system, which can be used as a standalone solution or in a supplementary role to radio-frequency (RF) or cellular network communications, can help guide customers to products within the store.

Recognizing that touchscreens and mobile devices are the advanced guard for the application of ubiquitous wireless communications in lighting control and elsewhere, both indoor and outdoor lighting fixtures can easily become part of a network that delivers data back to wherever it is needed, using both wired and wireless circuits.

The introduction of upgraded wireless protocols and standards, such as Zigbee, Bluetooth, and the new IEEE 802.11ac standard, makes network communications within a building easier. In particular, several features found in the new 802.11ac standard will be important for lighting use, including an increase in channel bandwidth, support for eight multiple input, multiple output (MIMO) spatial streams, and multiuser MIMO. Many facilities are deploying a much denser wireless LAN network, with an increasing number of access points being installed to handle building automation needs as well as laptop and smartphone users.

We can imagine that, in the future, all of the general lighting in the tenant-occupied spaces of a typical building will be wirelessly controlled through the Web or mobile apps using an open standard, a fixed network protocol, or a hybrid of the two — while recognizing that security is both a challenge and an opportunity.

Pay attention to the link between lighting and health. Because LED sources have high luminance, or source brightness, compared to legacy light sources — and because they usually lack a full color spectrum — individual LEDs in an array, phosphors, and electronic dimming can work together to create lighting tailored to support performance and human health.

Research is showing that the specific color produced by the LED chip within a luminaire can enhance human visual performance and offer therapeutic treatment value. While scientists continue to develop a deeper understanding of the link between light and health, people in the medical field are learning that arrays of color-changing LEDs can be programmed to replicate outdoor lighting conditions at different times of the day to help regulate circadian phase shift disorders — or more specifically, that blue light can be used to activate the circadian system.

Specialists suggest that during the active parts of the day, blue light (around 460 nm) should be present in larger quantities to support hormone production for alertness and activity. If blue light is then removed later in the day, it stimulates a reduction in cortisol, a hormone correlated with wakefulness, and the production of melatonin, which is associated with proper sleep and cognition, increases. Health care experts say the best way to accommodate circadian light is to have a luminaire, or the placement of light from a luminaire, simulate the appearance of the sky to stimulate a circadian response, a task easily handled by LED luminaires and controls. Using circadian rhythm lighting and putting control of color temperature and brightness in the hands of the staff and patients is an important trend.

Another indoor lighting application of a "tunable" white LED source is the ability to provide a "dim-to-warm" characteristic (for ambiance) that can mimic the way incandescent and halogen lamps dim, with the color temperature of the source becoming warmer as the light level drops. EC&M

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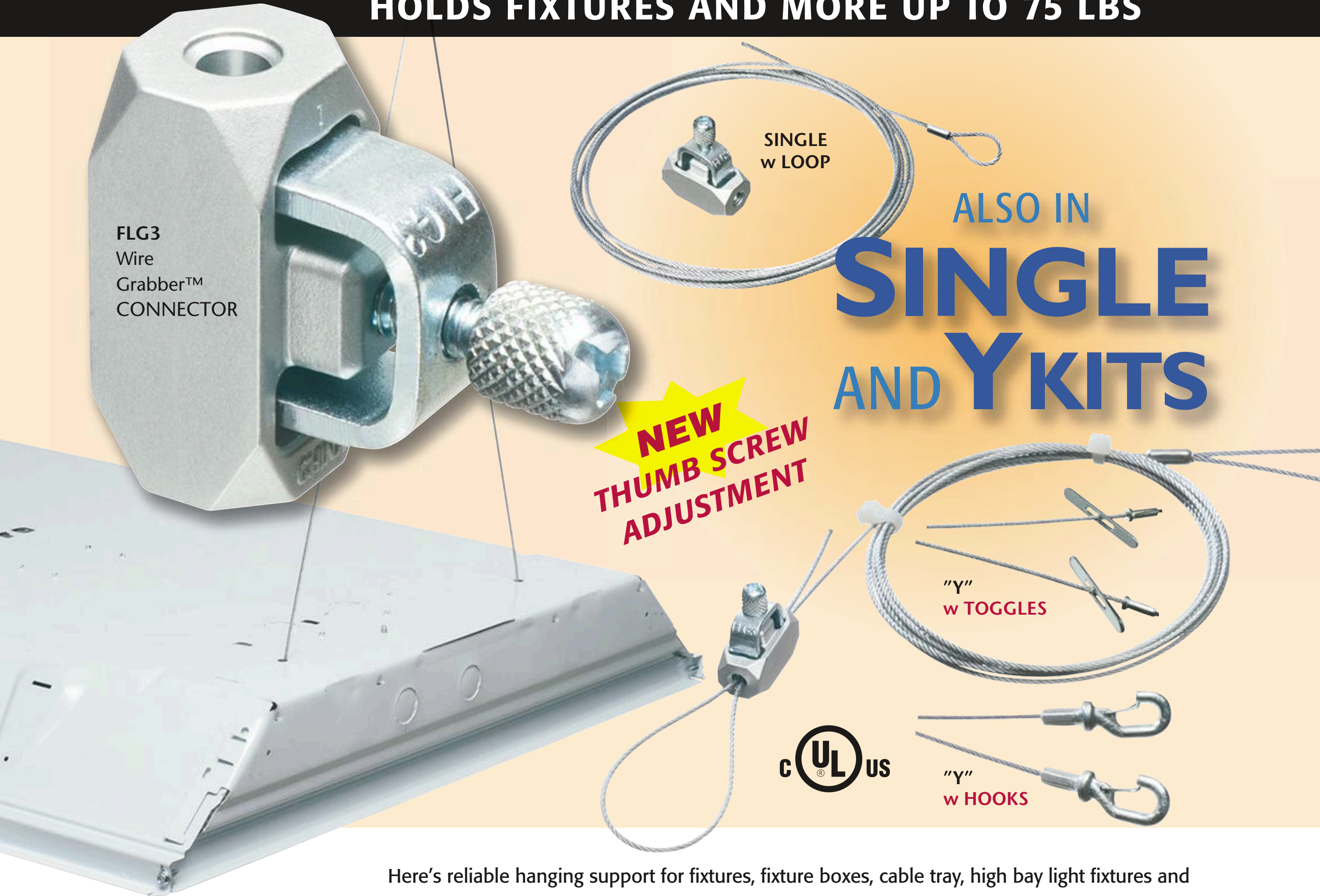

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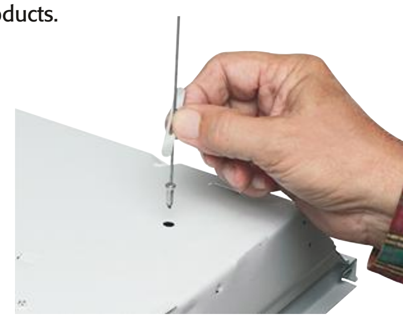

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CATALOG NUMBER	WIRE LENGTH
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DWYH0810	10'
DWY2H0810 (2 PK)	10'
DWYH0815	15'
DWYH0820	20'
DWYH0830	30'

"Y" w TOGGLES

CATALOG NUMBER	WIRE LENGTH
DWYT0805	5'
DWYT0810	10'
DWY2T0810 (2 PK)	10'
DWYT0815	15'
DWYT0820	20'
DWYT0830	30'

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Article 700: Emergency Systems

Keep emergency systems separate from other systems.

By Mark Lamendola, Editorial Consultant

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Photo 1. Emergency power systems help prevent additional emergencies when hospitals lose power.

Article 700 is the first in a series of NEC Articles about on-site power systems, including 700, 701, 702, 705, and 708. Each covers a different kind of system, differentiated by mission. The systems/missions include legally required systems, optional standby systems, and backup systems. All of these (except backup systems) are defined in Articles 701 and 702. The definition of a backup system depends on what you're backing up.

What about emergency systems? Such a system is actually a special case of Art. 701 (legally required) systems. In addition to being legally required, they are classed as emergency systems by the authority having jurisdiction (AHJ). That authority might be the state codes or an agency [700.1].

Emergency systems serve a specific function. They protect human life by providing the essential power and illumination [700.1] for egress and for the operation of emergency-related equipment, such as ventilation, fire pumps, and communication systems. For this reason, you find them at hospitals (**Photo 1**, above, and **Photo 2**, on page C14).

Emergency systems may provide power to elevators so people riding in them aren't stuck when an event occurs. This doesn't mean people can keep riding up and down in the elevators. Typically, the elevator control system automatically sends elevator cars to predetermined locations so the people riding them when the interruption occurs can safely reach emergency exits. These systems might continue operating so first responders can use the elevators rather than lug equipment up flights of stairs. The exact control scheme depends upon many factors, including local codes.

Size its supply to support emergency loads and other permissible loads [700.4] (those being legally required and optional standby loads).

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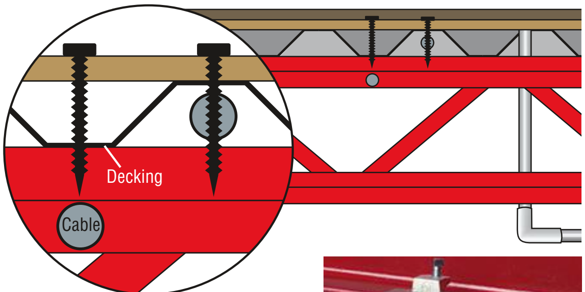

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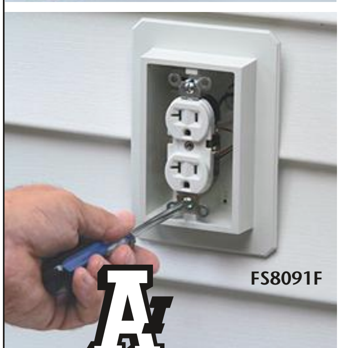

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Testing. Reliability is a key characteristic of emergency systems. For this reason, these systems must be witness-tested upon installation (and periodically afterward) [700.3]. The NEC doesn't define this testing, and it doesn't need to.

Each subsystem (e.g., generator, transformer) of the emergency system has its own applicable industry standards for installation and testing. The "witness" part means a third-party inspector (not the testing firm) observes the testing before signing off on it. Contact the AHJ to determine who this person can be and what documentation is required. That documentation will include such items as test equipment calibration reports, not just documentation of the actual system tests.

Obtain all of the applicable installation and testing standards well in advance, so you can properly design the witness testing program. If you wait until the installation begins, you'll probably take a major scheduling hit.


Mike G/Hemera/Thinkstock

Photo 2. Emergency power makes it possible to safely evacuate large, multi-story medical centers and other high-occupancy facilities.

Get it in writing. While the NEC is silent on the particulars of the acceptance tests or witness tests, it isn't silent on documenting those tests. It requires a written record of all tests and maintenance [700.3(D)]. At one time, "written" meant ink on paper. Things have changed, however. The term "written" has always meant "entered into your information system." But today, those systems are almost never paper.

Despite the wording, the NEC allows for the fact that we computerize our data today. One advantage inherent in paper is you have an audit trail. Make sure that advantage exists in your computerized data system also.

Bypass. You may provide a means to bypass and isolate the transfer equipment [700.5(B)]. This is beneficial for several reasons, including the ability to perform testing and maintenance without taking the emergency system offline. With a bypass, only automatic operation is offline. This poses another problem. What if the maintenance team forgets to put the system back online after conducting maintenance? Administratively, you can add a verification process in your maintenance procedures to prevent this.

Here's one way it's done. The lead tech must "sign out" the system for a specified period (e.g., two hours) to conduct maintenance. An operator puts the system in bypass. The operator returns near the end of the period to put it back in automatic while the tech watches. They both return to the operations desk to sign the system back in.

In power plants, status monitors show whether the system is in auto or manual. Power plants also have people assigned to monitor the status monitors. If you order a system with status monitors — and the facility doesn't have a staffed operations room like that of a power plant — today's technology provides a solution: the responsible party gets a notification, such as an SMS.

This problem and its solutions aren't covered by the NEC, but having a bypass that can inadvertently be left in bypass mode defeats the purpose of having an emergency system. Also make sure the bypass doesn't inadvertently kick the system into parallel operation [700.5(B)].

Alarming. Ensure the system provides at least the minimum requirements for visual and audio indication [700.6]. At a minimum, you need indicators to show:

- Derangement.
- Whether the battery system is

carrying the load.

- If the battery charger isn't functioning.
- If there's a ground fault.

Well-designed packaged systems easily beat the minimum requirements for alarms and signal devices. Look into a packaged system before deciding to "roll your own." You can, and probably should, get much more than the NEC minimums.

Think through your response strategy, and make the design support that. For example, instead of just local alarms, your system sends a text message to the plant manager, plant engineer, facilities manager, and production superintendent when Event X happens.

It's important to locate ground faults quickly. But doing so can tie up maintenance personnel so other failures go unmet. One solution is to pre-arrange a response with a local contractor that is equipped to quickly locate and repair such faults. Your system sends a text message to the contractor, a designated plant electrician, and the plant engineer simultaneously. The plant engineer coordinates with production and other parties while the cavalry is on its way.

If the facility doesn't have its own maintenance staff and a plant engineer, making these advance arrangements is even more critical. The facilities manager should have a response properly planned and contracted. When a fault occurs, it won't trigger several hours of panic.

Marking. If equipment is part of the emergency system, mark it as such [700.10(A)]. That includes all boxes, enclosures, panels, transfer switches, and generators. Basically, if a piece of equipment is on the emergency system drawings, give it a permanent label saying it's part of the emergency system. Mark the raceway, too.

One reason to mark all of these items is to help prevent mixing other system wiring or equipment in with the emergency system power wiring and equipment [700.10(B)]. There are five common-sense exceptions to this [listed in 700.10(B)].

Source it. The emergency system must have a power source in case the normal supply is lost [700.12]. Otherwise, it's not going to be there when you need it! The requirements for this power source are in Part III. The NEC permits five classes of power source:

- *Storage battery [700.12(A)].* These must meet specific requirements but are usually the lowest-cost solution.
- *Generator set (gen-set) [700.12(B)].* This won't work without also having storage batteries for ride-through while the generator comes up to power.
- *Uninterruptible power supply (UPS) [700.12(C)].* These must comply with the requirements for batteries [700.12(A)]. Also with the requirements for gen-sets [700.12(B)] if the system has a gen-set. The UPS must have separate service conductors.
- *Fuel cell system [700.12(E)].* Among the requirements are the fuel cell can't serve the emergency system if it also is the normal power supply (add a separate fuel cell for that).
- *Unit equipment [700.12(F)].* This includes items such as battery-powered exit lights.

Other requirements. You'll find special requirements for lighting and power in Part IV, control of lighting circuits in Part V, and overcurrent protection in Part VI. A key theme in the lighting requirements is you must arrange the system such that only authorized personnel have control of emergency lighting, and you can't make that control difficult for them.

The 2014 NEC added a clarifying paragraph for the selective coordination requirements. It's no longer a DIY for the plant electrician. Now, it must be done by a licensed professional engineer or other qualified person [700.28].

No emergency here, boss. The whole point of an emergency system is to prevent corollary emergencies when a major event happens. If there's a fire, first responders have enough on their plate without also having to free people from elevators that lost power — nor do they have time to hunt for people who couldn't find their way out in the dark.

Complying with the NEC minimums is only part of what must be done to provide a reliable emergency system. Make sure that system reliably supports your emergency response plans. EC&M

Lamendola is an electrical consultant located in Merriam, Kan. He can be reached at comments@mindconnection.com.

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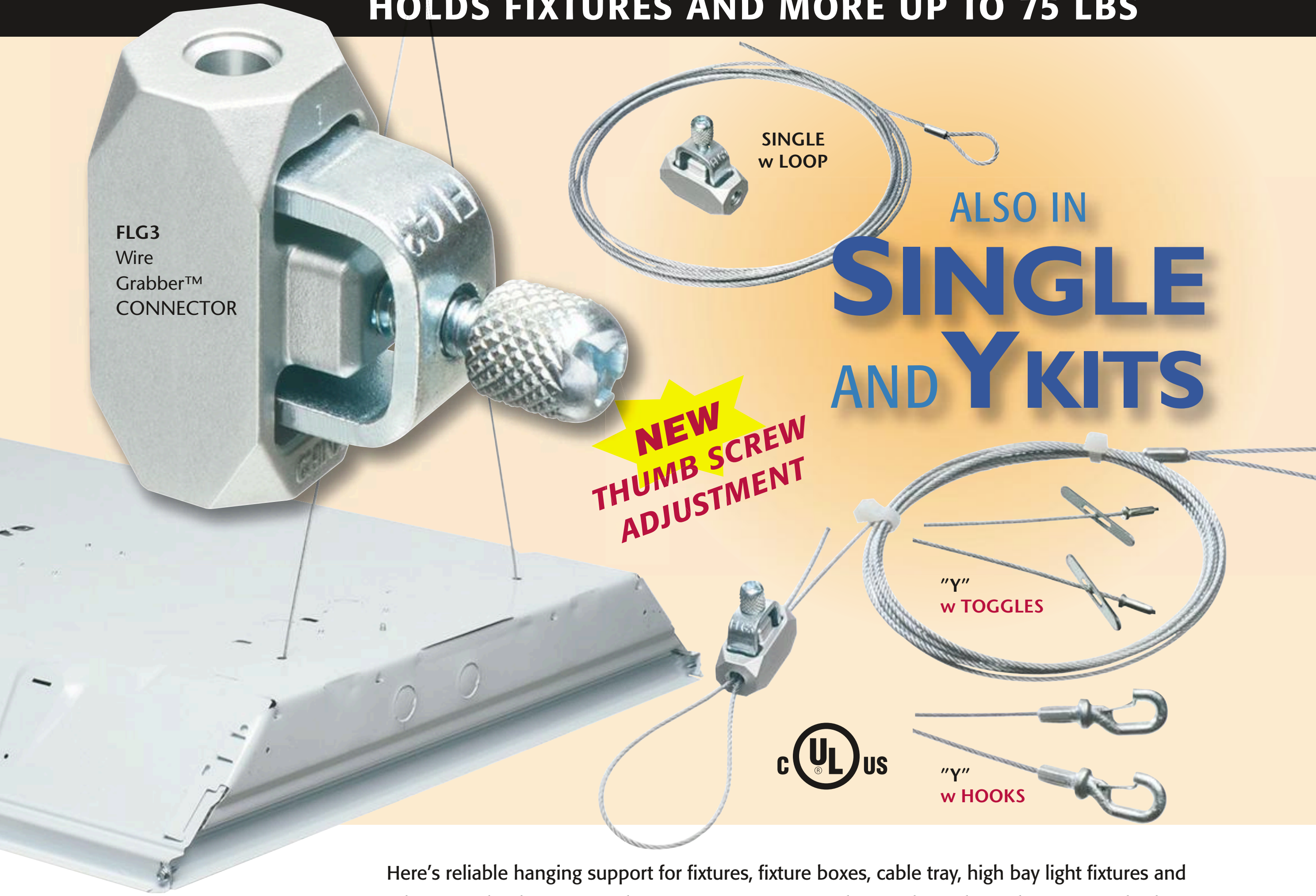

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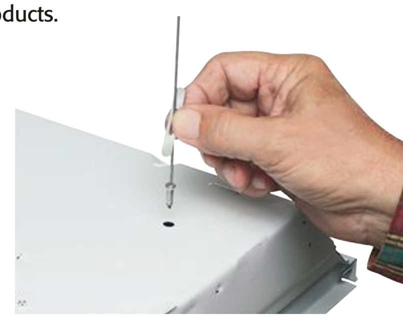

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SINGLE LOOPED END

CATALOG NUMBER	WIRE LENGTH
DWB0805	5'
DWB0812	10'
DWB0815	15'
DWB0820	20'
DWB0830	30'

"Y" w HOOKS

CATALOG NUMBER	WIRE LENGTH
DWYH0805	5'
DWYH0810	10'
DWY2H0810 (2 PK)	10'
DWYH0815	15'
DWYH0820	20'
DWYH0830	30'

"Y" w TOGGLES

CATALOG NUMBER	WIRE LENGTH
DWYT0805	5'
DWYT0810	10'
DWY2T0810 (2 PK)	10'
DWYT0815	15'
DWYT0820	20'
DWYT0830	30'

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Five Trends to Track in the Health-Care Sector

As the hospital market begins to release new work, here are ways electrical contracting firms can leverage opportunities in this market.

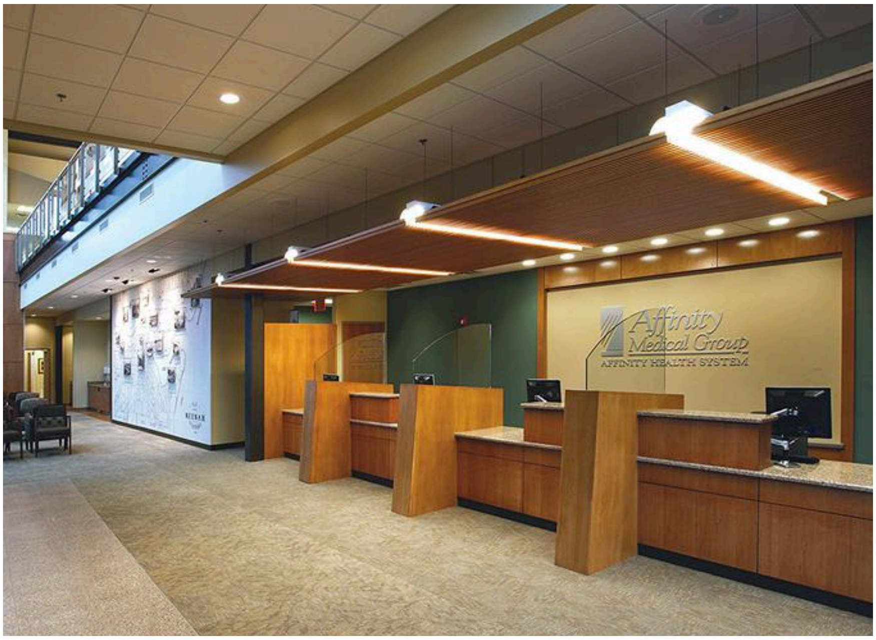
Patient comfort, security, and overall enhanced experience are leading to more high-tech systems in patient care rooms like the one shown here installed by ERMCO, Inc. at the Community Rehabilitation Hospital in Indianapolis.

By Amy Fischbach, Freelance Writer

The aging of not only the population, but also the nation's hospitals, is strengthening the health-care market. Case in point: Health care ranked as one of the top three markets for more than half of *EC&M*'s 2014 Top 50 electrical contractors last year.

In certain pockets of the country, this market is starting to show signs of life again as hospitals are investing in upgrades, building new facilities, and constructing stand-alone clinics. At the same time, however, other major hospitals are still taking a wait-and-see approach due to uncertainty stemming from the Affordable Care Act, says Ken Simonson, chief economist for the Associated General Contractors of America.

"Hospitals have been holding off on some major spending decisions and construction projects until they have a firmer idea of how the hospital utilization and reimbursement rates will be affected," Simonson says. "By the end of this year, they should know more as the Act is fully implemented."



Faith Technologies installed fiber-optic/copper cabling, a fire alarm system, intercom/public access, security and video system, and all electrical in the Affinity Medical Group Neenah Clinic in Neenah, Wis.

Hospitals' uncertainty and cautiousness to invest in future improvements, however, may have already taken their toll. Due to the extremely reduced investment, the construction industry felt an immediate impact that may take years to overcome, says David Peterson, senior vice president for ERMCO, Inc., an Indianapolis-based electrical contracting firm.

While some health-care providers have put projects on the backburner due to uncertainty, demand is now increasing, and hospitals are realizing they need to do something to keep up with the demand, says Kevin Haynes, senior consultant for FMI Corp. For example, Faith Technologies' health-care clients are starting to release work and spend money on new projects, says Michael Bowman, a vice president for the Menasha, Wis.-based electrical contracting firm.

In California, upgrading facilities to meet the legislature's demands for emergency preparedness — primarily structural seismic standards — continues to be the driving force behind new hospital construction, says Ed Noble, director of pre-construction for Helix Electric, a nationwide electrical contracting firm.

"The state government has twice extended the deadline for compliance, with 2020 now representing the deadline," he says. "Most major facilities have found that replacement is a better value than retrofit. California can expect to continue to see a strong health-care construction market for at least the next five years."

For electrical contractors interested in health-care market work, here are five key trends that are driving steady growth.

1. Focus on new cabling and connectivity. As hospitals begin investing in upgrades and new construction projects, they are hiring electrical contracting firms to install new cabling to support the latest technology.

For example, due to technological advances, electricians are now facing additional requirements related to pathways and rough-in to accommodate the larger Cat. 6A cable, says Gene Burcham, vice president of the systems group for ERMCO. In turn, this work requires additional coordination with other trades and in the field.

Daniel Holland, president of Star-Lo Communications, says the new trend for hospitals is to install this higher-grade cable to support higher bandwidth access points. Because hospitals are facing new standards in wireless applications and must install a

Photo courtesy of Susan Fleck Photography

The use of alternative procurement methods such as IPD, which was used here on the Riley Simon Tower Children's Hospital in Indianapolis, allowed ERMCO and the other IPD team members to design and install the various patient care rooms to precisely meet the client's needs.

greater density of wireless access points (WAPs), it has generated a lot of work for the company's low-voltage technicians, who are doubling the number of access points in several local hospitals. In addition, they are increasing the amount of Wi-Fi and cellular coverage for several major hospital wireless networks by installing WAPs in patient rooms and common areas.

To enhance the patient experience, hospitals are also shifting from television over coax cable to television over the Internet. When the television becomes a device on the wireless network, patients can play games or surf the Internet from the comfort of their bed rather than only being able to flip through TV channels.

Furthermore, low-voltage electrical contracting firms must set up two different private networks. A clinical network supports the patients and allows the medical staff to transmit exam results and records electronically to other clinics. An information technology network then handles record-keeping and process-related information technology.

In addition, Holland says his technicians are also setting up a robust wireless network to support the growing number of mobile devices used within the hospitals. For example, the technicians set up a distributed antenna network, which enables cellular service in the hospitals and allows patients and visitors to access the 3G service from their local providers.

"There is so much wireless usage within some hospital facilities that it causes electromagnetic interference on their wired networks," Holland says. "The trend is to not eliminate the wired connections, but instead to supplement the network with a lot more wireless density and bandwidth."

2. Reaching out to the community. Another key trend within the health-care market is the emergence of stand-alone emergency clinics, surgical centers, and non-acute care facilities in retail stores, Simonson says.

In some cases, these clinics may be taking business away from the hospitals by directly competing with them, Simonson says. In other situations, however, these free-standing emergency departments are actually affiliated with the major medical systems, Bowman says.

"One of the biggest trends that we are seeing is a focus outside the core institution of a hospital and not the typical independent 'doc in a box,'" Bowman says. "Instead, we are seeing more of an uptick in free-standing emergency departments — either stand-alone or coupled with a medical office building — as well as outpatient surgical centers."

One of the key technologies allowing these small clinics to be integrated into the larger hospital's network of care is the inclusion of Tele-Medicine units, Noble says. These sophisticated audio/visual stations can include an array of metrics permitting specialist clinicians in the home hospital to remotely interact with and evaluate patients in these separate facilities, he says.

By building these new facilities, the major health-care systems can lessen the emergency room wait time, reach out to the outlying community, and treat patients closer to home. Then, if they need to be admitted, they can be transferred to the local hospital, and their personal and medical information is already in the system.

Because these clinics often include a much smaller amount of electrical work than in a traditional hospital construction project, they are starting to open the field to smaller electrical contracting firms, Haynes says. While only a handful of electrical contracting firms may have the capacity and experience to bid on a $300-million hospital project, a smaller project in a medical office building may attract more bidders, he says.

"It allows for new players to come in who haven't worked with an owner before," he says. "Then if a company knocks it out of the park on a smaller project, it may get a chance to bid competitively on a larger job when the economy improves and the demand for health care skyrockets."

3. Reviving aging facilities. Along with building smaller facilities that reach out to the community, hospitals are also hiring electrical contracting firms to upgrade their decades-old aging facilities. For example, hospitals are hiring companies to upgrade finishes, install interactive systems, and improve lighting and controls.

"We are seeing a lot of the facilities investing in remodels, upgrades, and additions to try to get caught up with technology and meet the ever-changing standards and codes," Bowman says. "Owners are trying to figure out what is the best to spend on today so it won't be outdated tomorrow."

For example, a lot of the hospitals that were built in the 1970s and 1980s are behind when it comes to the emergency power requirements. As such, they must be upgraded to comply with current

Influences Affecting Health-Care Construction

Over the last 20 years, health care has been one of ERMCO's primary markets. The Indianapolis-based firm has participated in many evolutions in the industry — from new hospitals to medical office buildings to tenant renovations. David Peterson, senior vice president, shares four more trends that are not only impacting his firm, but could also affect other contractors in the future.

Shifting to prevention. The health-care industry has undergone many changes over the last few years, Peterson says. For example, he says the transition to preventive care and a minimum for overnight patients has continued to drive the development of clinics and the approach to outpatient and ambulatory care.

Focusing on improving security. In the health-care industry, security is in a critical transition, Peterson says. For example, hospitals are installing card access and video monitoring systems to tighten up information security and access/control of hospital personnel, patients, and visitors.

Serving the aging population. As the health-care needs of the Baby Boomer generation increase, Peterson predicts there will be a drastic increase in the services sought by that population. Cardiology and orthopedics may have the largest noticeable impact, but expectations will shift as hospitals start to focus more on other areas, including the patient experience as a whole.

Customizing solutions. Hospitals are always trying to install the latest technology to better serve their clientele, improve the productivity of their medical team, and compete with other facilities. "Through increased understanding of technology advancements, electrical contracting firms have an opportunity to be more involved in developing these types of solutions," Peterson says.

Photo courtesy of Helix Electric

Helix Electric installed two new transformers as part of the 12kV A/B underground distribution system upgrade at the San Francisco Veterans Administration Medical Center.

standards, Bowman says.

"Back then, the amount of power required for a given room was one or two outlets or circuits," he says. "Over time, the emergency power system requirements have become much greater, which, in turn, has taxed the older systems and requires an increase in the overall capacity."

The hospitals must also implement a preventive maintenance program for their emergency power system and ensure that the equipment is regularly maintained and tested. This requirement is driving more opportunities for electrical contracting firms to manage this maintenance work in the health-care sector, Bowman says.

4. Conserving energy. As hospital administrators renovate their facilities, they often look to save energy and increase efficiency. According to Bowman, two of the main ways they can save energy on the electrical side is by installing more efficient mechanical systems and lighting and control equipment.

"The mechanical systems are one of the biggest users of energy within a hospital, and by moving to more efficient systems and better control, you can see a big difference in the decrease in the overall energy usage," he says. "Additionally, by integrating the building management systems with new and improved lighting control systems, customers can maximize energy savings as well."

Faith Technologies is one contractor seeing an increase in the amount of LED lighting on projects, which hospitals are using to illuminate both exterior and interior spaces. Similarly, E-J Electric Installation Co., a Long Island, N.Y.-based electrical contractor, is also installing LED lighting for several of its health-care clients, says Chairman Bob Mann.

Sustainability and efficiency are driving many design decisions in the health-care market, says Peterson of ERMCO.

"Health-care facilities are major power users and operating as efficiently as possible has become critical to their business model," Peterson says. "Also, with new technology comes a responsibility to protect the health-care industry's ability to maintain operations through environmental and any other potential interruptions."

Haynes says while he sees contractors focused on making improvements related to energy efficiency and sustainability, he is seeing a decrease in the number of projects applying to be LEED certified, simply from an economic standpoint.

"The momentum with green building has continued, but people may be less likely to try to get their buildings LEED certified during more difficult economic times," he says.

By decreasing its energy usage, however, a hospital can decrease the life cycle costs, Haynes points out.

"Owners may see that there are more costs upfront to incorporate the efficient equipment, but at the same time, if they look at those costs over the lifetime of the building, they will see the savings pay off," he says.

5. Pumping up project productivity. With regard to project management, health-care projects are many times leading the way when it comes to saving money, time, and labor. For example, contractors and economists alike are seeing a focus on prefabrication, building information modeling (BIM), and lean construction on health-care projects.

Faith Technologies has been using prefabrication for several years because it not only makes the electricians more productive in the field, but also because the owners and end-users are requesting it. For example, the contractor has worked on projects where an entire corridor has been prefabricated collaboratively by the trades and then put into place. The firm has also prefabricated entire patient bathrooms as well as electrical rooms including large feeders and panelboards, which are constructed off-site and assembled on-site.

"We push prefabrication to the limit and are looking to take advantage of all the opportunities we can to prefab," Bowman says.

One way the contractor is able to prefabricate the building components ahead of time is by extracting exact, detailed drawings from a BIM. By fabricating electrical systems ahead of time, the electricians can better meet deadlines, even on projects with accelerated schedules.

"When you perform the work in a controlled environment, it increases safety and quality control, which, in turn, minimizes rework," Bowman says. "On large projects, trades are often stacked on top of each other, or the electricians must work in tight spaces. By performing as much of the work as possible off-site, you minimize the overlap of multiple trades trying to work in the same area at the same time."

To handle the increased demand of

not only BIM, but also early involvement on projects, Faith Technologies has bolstered its pre-construction staff to more than 100 designers, virtual design and construction (VDC) modelers, engineers, and preconstruction managers to meet its customers' needs and provide maximum value.

"BIM is a must-do today," he says. "It is an important component, and owners are looking to have a fully integrated model with all of the major systems."

Noble says BIM has revolutionized the way MEP systems are built in hospitals, and it goes hand-in-hand with the full implementation of off-site prefabrication.

"When you have a fully developed and coordinated 3D model, you can proceed with massive prefabrication assemblies with the total confidence that those assemblies will fit smoothly into the overall construction plan," Noble says.

As health-care clients are increasingly requiring their electrical contractors to be proficient in both BIM and prefabrication, they are also taking a lean construction approach to their new construction projects. To minimize cost and maximize value, some of Faith Technologies' customers are asking the MEP trades to get involved early on in the process for a best-value approach, Bowman says.

Owners are learning, however, that the earlier they engage the MEP subcontractors in the design process, the better their project comes together when they hit the site, Noble says. The organization has had first-hand experience with failures resulting from the old model, and, as such, has consciously worked to increase its pre-construction capacity.

"Lean construction and integrated project delivery in the health-care segment is being driven by owners who have come to see the old design/bid/build model as too cumbersome, costly, and ineffective for large, complex projects like hospitals," says Noble. "The best preconstruction effort yields the best construction product in terms of quality, time, and value."

By becoming well-versed in different delivery methods and becoming experienced with BIM and prefabrication, electrical contracting firms can position themselves to take advantage of emerging opportunities in the health-care sector. That way, when the uncertainty dissipates and hospitals release more work, they will have the expertise, available workforce, and technological know-how to win much more work. **EC&M**

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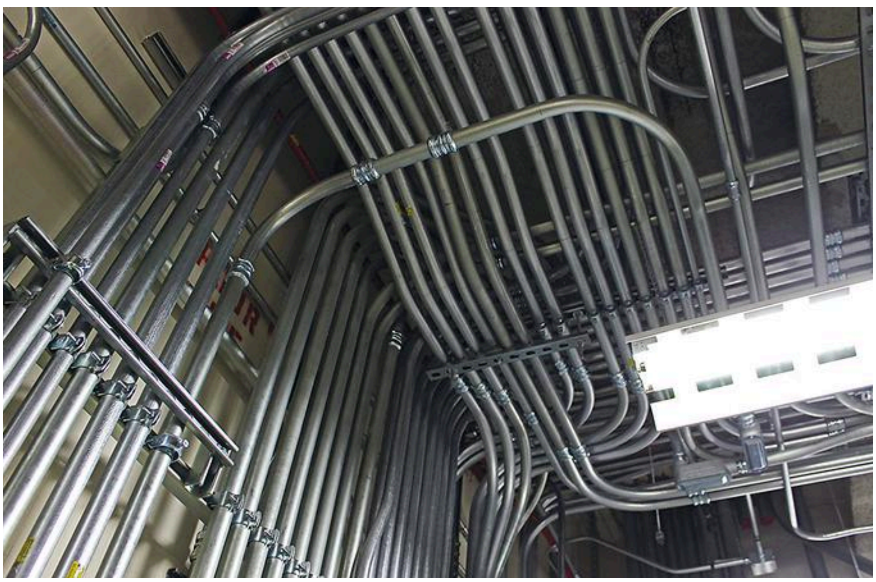

The implementation of BIM, prefabrication, and LEAN principles allows ERMCO, Inc. to accomplish intricate conduit installations, such as this one at Riley Simon Tower, in the most cost-effective and proficient manner possible.

Common Causes of Change Orders

How to handle the unexpected that almost inevitably pops up on every construction project

Iurii Kovalenko/Hemera/Thinkstock

Changes in scope on a construction project are typically the result of an updated design, plan revision, requests for information (RFI) response, or returned submittal.

By Adam Cooper, Ascent Consulting, Inc.

Change orders are an integral part of every construction project. No amount of design, engineering, planning, or scheduling can completely eliminate the potential for construction changes with cost impacts to the contractor. Something always seems to require the installer to do something other than what was planned, estimated, bid, or previously installed.

Let's begin with some definitions for clarification. A change order proposal (COP) is a document prepared by the subcontractor and is submitted to the general contractor (GC) or owner. It may also be called a proposed change order (PCO) or a cost estimate (CE).

A change order (CO) is a document prepared by a GC or owner that legally changes the contract value, scope, and/or terms to include items from a COP. A GC may accept a COP in part or in whole, and the resulting change order is then generated. Both the GC and the subcontractor must sign the CO to accept it as written before it becomes integrated into the contract; it is not legally binding without these signatures.

Most change orders are the result of a combination of two or more factors. With that in mind, let's look at the most common causes of change orders.

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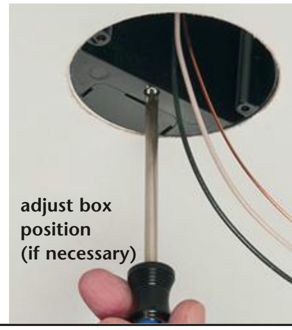

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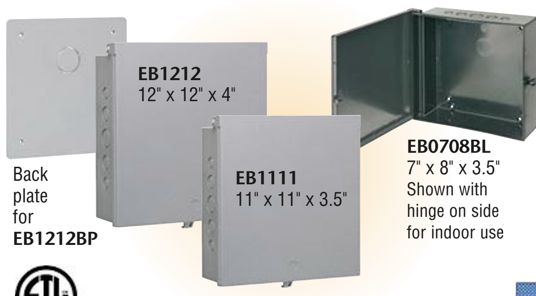

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Changes in scope. The most common types of changes on a construction project, changes in scope, are typically the result of an updated design, plan revision, requests for information (RFI) response, or returned submittal. COP pricing typically includes a detailed estimate of the changes between the original design and the new conditions, often referred to as the variance or delta between the two ("delta" is a mathematical term that means "variation" and is used often in estimating). Pricing will include materials and labor costs associated with the change, and might also include rental equipment and sub-subcontractor costs.

Scope changes may also be the result of constructability issues that arise during the installation process. This might occur when there is an unforeseen conflict between trades or a physical inability for things to coexist in a shared space. For example, a conduit run and an HVAC duct cannot be in the same place, and one will need to be re-routed to avoid conflicting with the other. In this case, the HVAC duct will typically take precedence due to engineering and design limitations on duct bends, so the electrical system will be re-routed to avoid the conflict. If the re-routing causes significant time and/or material impacts, then the electrical contractor should be able to submit for the increase in scope. This can be driven by the RFI process, if time allows, but may also be generated by a field directive from the GC in order to avoid schedule delays while waiting for an RFI to make its way through the formal process.

Another type of COP results from changes or repairs to previously installed work. In this case, there would also be a demolition or de-construction component to the COP pricing. The subcontractor will need to remove something that was already in place in order to make the change or replace the damaged installation, so additional labor costs would be included for these types of changes.

Material changes resulting from the submittal process constitute another reason to generate a COP. As electrical contractors, this will most often occur through the light fixture and power distribution equipment submittals. Fixture pricing is estimated from the fixture schedule and specifications provided at bid time. Fixture submittals are generated after award of contract and sent to the designer/owner for review and approval. Once received back by the subcontractor, any changes made by the design team or owner would be priced, and a COP would be generated. This would typically be a material cost only change, but could include a labor component if the fixture change is significant. For example, if recessed cans were changed to pendant fixtures or chandeliers, there would likely be an increase in man-hours required for the installation.

Power distribution equipment changes typically occur when the engineer designs the equipment or system without a specific manufacturer in mind, and the design is often representative and diagrammatic in nature. Through the submittal process, it may be determined that the design is not practicable or available, and a reconfiguration or additional pieces of equipment may be required. The subcontractor would then have the opportunity to submit a COP for any additional costs related to these equipment changes.

Material price escalation can be another reason to generate a COP. While this is a fairly infrequent situation, it does occur and can be justified if material prices experience a drastic increase outside of normal market fluctuations. Electrical contractors would most commonly experience this with copper and aluminum wire pricing, but could also be impacted by fluctuations in the steel market as well — as this would affect products like strut, conduit, fittings, and enclosures. As the commodities markets experience price fluctuations, so might the cost of goods that a contractor would purchase.

We previously touched on this topic in last month's piece about centralized purchasing. Larger contractors will commit bulk orders for copper and aluminum and lock in pricing for the year or duration of a project, thereby insulating themselves from the day-to-day market variations that might affect materials costs. However, smaller contractors typically do not have this luxury and are subject to these variations and escalations. Should a large material escalation occur (typically >10-15%), the contractor might be able to submit a COP for material cost increases. While this is not guaranteed to be approved — and may, in fact, be precluded by language in the subcontract agreement — it is worth noting that the opportunity exists and should at least warrant a conversation with the GC.

Changes in schedule. Changes in schedule most often occur as delays, extensions, compression, and out-of-sequence work. Most subcontracts contain specific language about delays and preclude a subcontractor from recovering costs due to schedule delays. Instead, the subcontractors are afforded a schedule extension equal to the amount of time they have been delayed. These clauses typically contain very specific terms and conditions for notification requirements and limitations for such compensations. Therefore, it is important to read and understand these terms for each project, as they vary between projects, contractors, and subcontracts.

Should the GC or owner extend the duration of the project past the contractual completion date or time frame for reasons outside of the subcontractor's control, the subcontractor is typically entitled to a contract modification to provide compensation for the "Extended General Conditions" required by the extension. Typical EGCs would include costs for salaried positions (e.g., project managers, superintendents, administrative personnel, etc.), job-site office and rental equipment, small tools and consumables, and any other direct project costs that are incurred as a result of the extended schedule.

Schedule compression is becoming more prevalent in the construction industry, typically to combat schedule extensions. There are a myriad of reasons for this (which we won't explore in this article), but they mostly boil down to financing and construction loan terms. Project schedules are built with little "float" or extra time, and are very sensitive to unforeseen delays. Any delays must be overcome to keep the project on schedule without using up all of the float, so activities are compressed and trades are "stacked."

What might this look like? Let's say that due to a delay (i.e., weather, failure to perform by another subcontractor, unforeseen conditions, etc.) an activity or area that has been allocated on the master schedule as a 10-day activity must now be performed in five, and multiple trades are now working in the same area at the same

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time instead of one after the other. The result is that more workers are required to perform the same scope of work in a shorter duration, overtime costs are incurred, and the workers' efficiency is reduced due to the congested work area. These conditions all have a direct and measurable impact on cost and are compensable.

There are plenty of resources available to help contractors understand and quantify these cost impacts more clearly, including schedule compression courses offered by trade organizations. There are also plenty of books on the subject, such as *The Impacts of Planned and Unplanned Schedule Compression Or Acceleration on the Labor Productivity of Contractors* by David Alan Noyce and *Impact of Overtime on Electrical Labor Productivity: A Measured Mile Approach* by Awad Hanna.

Subcontractors should also be aware that there are scheduling professionals who can assist with quantifying such cost impacts and assist with presenting to an owner or GC for compensation.

Out of sequence work may also constitute an opportunity for compensation. Much like delays, most subcontracts contain language that allows a GC to redirect a subcontractor's workforce or alter the construction sequence as needed, often with as little as 24 hour's notice. This allows the GC to avoid cost impacts from subcontractors due to unforeseen obstacles that may arise during construction. For example, let's say you're scheduled to begin work in area "A" on Wednesday. On Monday, the GC discovers it has a problem in area "A" that must be corrected before any work can start. The GC can direct you to work in an alternate area while correcting the situation in area "A" without incurring a cost impact for the redirection.

While there are typically no limits on this ability written in the contract, it is understood that you must be given the originally schedule duration to complete your scope in area "A." If not, then the redirection may result in schedule compression when you are finally cleared to work in area "A," which is compensable, as previously explained.


satori13/iStock/Thinkstock

Weather impacts and acts of God are almost always addressed in the subcontract with specific legal language and should be evaluated on a project-by-project basis.

Changes in site conditions. The final group of cost impacts we will explore consists of unforeseen conditions, weather, acts of God, and safety. Unforeseen conditions are most common in subgrade activities (i.e., excavation, rock removal, de-watering) and in renovation and rehabilitation work (i.e., asbestos, unknown structural interferences). These usually result in time and material impacts, and may also carry a schedule impact, which are all compensable.

Weather impacts and acts of God are almost always addressed in the subcontract with specific legal language and should be evaluated on a project-by-project basis. Normally, no compensation is available for schedule delays resulting from these occurrences, but time extensions are granted. If the occurrence results in damage or rework, these costs would be compensable to the subcontractor.

Safety is a more complicated subject and, as such, more difficult to substantiate and recover costs. A safety incident that shuts down a job site for an extended duration (days or weeks) would carry a compensable cost impact, but only if your company was not the reason for the shutdown. Costs may include demobilization and remobilization, schedule extension, extended general conditions, additional safety training, and travel-related costs if the project is outside of your local territory. All of these may be submitted for compensation to the GC or owner, dependent on the nature of the safety incident that closed the job site.

Now it's your turn. I'd love to hear your thoughts on this topic.

• What have you failed to recognize as a valid reason for a change order proposal?

• What have you experienced and not been compensated for?

• What have you submitted and had rejected by a GC or owner?

• What would you like to learn more about?

• What's been your best experience?

You can drop me a confidential note at the email below, or share your thoughts via the comments area on the *EC&M* website for all to see and learn from. **EC&M**

Cooper has more than 20 years of electrical construction and contracting experience. He has worked for several of the largest electrical contractors in the United States, and holds a Class II Unrestricted Electrical Contractors license in the state of Georgia. He currently is president of Ascent Consulting and can be reached at cacooper@ascentconsult.net.

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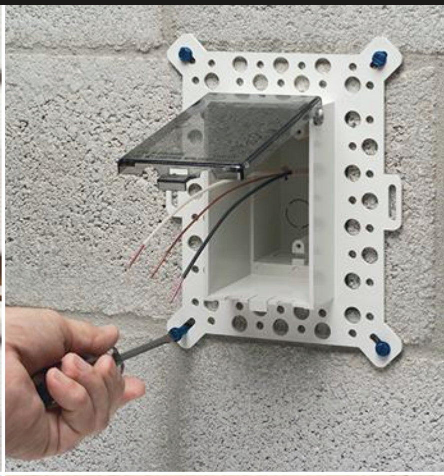

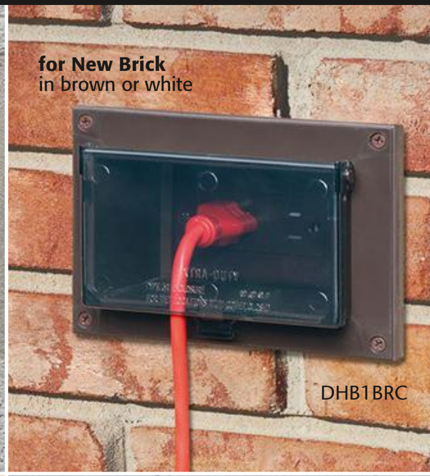

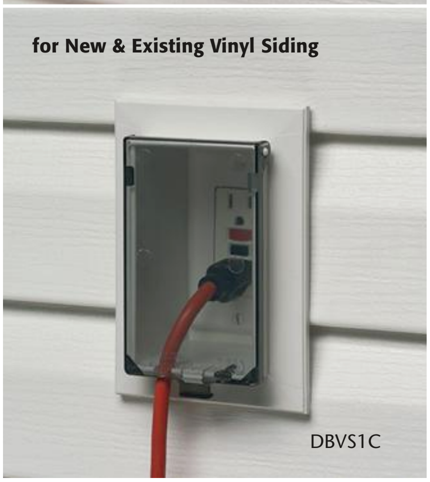

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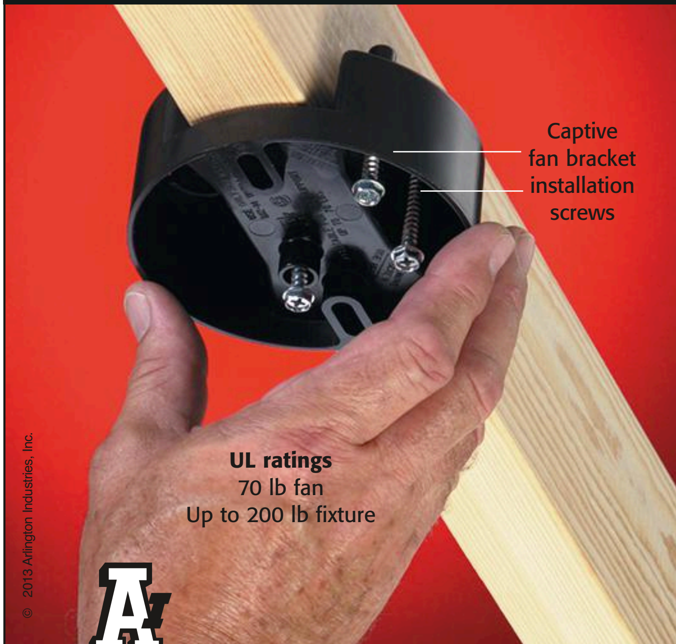

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Arlington's fan/fixture boxes offer the fastest, most secure way to mount a fan or fixture. The box press-holds to a 2x4 where it stays firmly in place until the captive center screw is tightened, mounting it directly to the joist.

No pieces to lose! All box and bracket installation screws ship captive. Also included, an installed mud cover and NM cable connector.

- Easy installation in new construction
- For 1/2" and 5/8" drywall
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10.3 cu. inches

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FLUSH CEILING INSTALLATIONS

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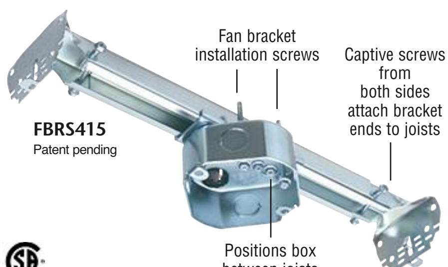
Flush ceiling installations
FBRS415 is designed for ceilings up to 1-1/4" thick. For 1/2" ceilings, use the pre-bent positioning tab. For other ceiling thicknesses, bend along the appropriate score line.

- 15.6 cu. inch box ships with captive screws, mud cover, installed NM cable connector



UL ratings
70 lb fan/90 lb fixture at 24" oc
70 lb fan/150 lb fixture at 16" oc

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PRODUCT NEWS

Adjustable wrenches

Xtra Slim Jaw adjustable wrenches are offered in 6-in. and 8-in. sizes and are 40% thinner than a regular wrench of the same size, according to the company. Featuring 3/16-in. jaws for 20% greater jaw capacity, the wrenches include Code Blue grips and are properly balanced to avoid weak points. In addition, the tool's jaws are imprinted with standard and metric measurement scales.

Channellock

Circle 250

Mini bolt cutters

CoBolt mini bolt cutters feature ¼-in. jaws as well as etched blades, which the company says require less force to make challenging cuts. Constructed with micro-structured cutting edges, the bolt cutters are designed to prevent thicker, round objects from slipping out during a cut, yet they can easily grip both round and flat objects in one tool. Features include a gripping zone behind the joint for reliable gripping of wires and pulling nails and ergonomic handles.

Knipex Tools

Circle 251

Anti-fog lens coating

HydroShield anti-fog lens coating delivers up to 60 times longer (more than 2 min.) fog-free protection and two times greater scratch resistance than competitive anti-fog coated products, according to the company. Available on four of the top-selling Uvex eye protection products — Genesis, Genesis XC, and Protégé safety glasses and Stealth safety goggles — the coating is permanently bonded to the lens and will not wear off after extended wear or repeated cleanings.

Uvex by Honeywell

Circle 252

EMT couplings

Mighty-Merge Two-to-One EMT couplings are designed to save time and material when joining two lengths of EMT conduit into one. The cULus-listed fittings are suitable in applications where: limited knockout space is available entering an enclosure or panel, to isolate circuits, coordinate installation speed up and down block wall construction, in an OEM design requiring tight parallel raceway management, or in place of pull boxes and supports. In addition, the couplings' single set-screw inspection cover provides easy access to cables or conductors.

Bridgeport Fittings

Circle 253

freeproductinfo.net/ecm

Arc-flash relay

The AF0500 arc-flash relay offers a plug-and-play installation design that is suitable for retrofits in electrical equipment, including switchgear, transformers, substations, motor control centers, load banks, and more. The relay supports four light sensors that allow it to sense an arcing fault, respond in less than a millisecond, and send a trip signal to an upstream breaker to interrupt the fault. In addition, the product does not require PC configuration and is equipped with a visual indicator called Heartbeat to monitor the health of the sensor.

Littelfuse

Circle 254

Battery-powered crimper

The PAT500SJ Series pistol-grip style 6-ton 18V Li-ion battery-powered crimper with interchangeable cutting jaws accepts the company's standard "W" and "X" style crimping dies, and offers copper crimping capacity from No. 8 wire up to 500kcmil and No. 8 wire to 350kcmil for aluminum cable. With the interchangeable cutter jaw, the tool allows for copper cuts up to 500kcmil, aluminum cuts up to 636kcmil, and ACSR cuts up to 556kcmil. Other features include an audible "pop-off" that indicates a properly completed crimp.

Burndy

Circle 255


Continuing Education
Your Weekends
Are Important...
"...as for me and my house, we will serve the Lord." [Joshua 24:15]
2

By Tom Zind, Freelance Writer

LEDs Still a Mystery to Many Contractors

As LED products continue to flood the marketplace, electrical contractors must balance the appeal of online buying expedience with the need to fully grasp a technology still shrouded in uncertainty.

Held up as one of the proven, readily deployable technologies that could put a big dent in global energy consumption over time, LED lighting products are drawing the interest of ever more electrical contractors looking for avenues into the lucrative and growing energy-efficiency market.

Enjoying full-throated support and promotion from the federal government — notably via the U.S. Department of Energy's (DOE's) Office of Energy Efficiency & Renewable Energy — LEDs continue to reap benefits through utility and governmental subsidy programs as well. The technology is also a likely benefactor of predictions that the energy services company (ESCO) business is poised for more growth.

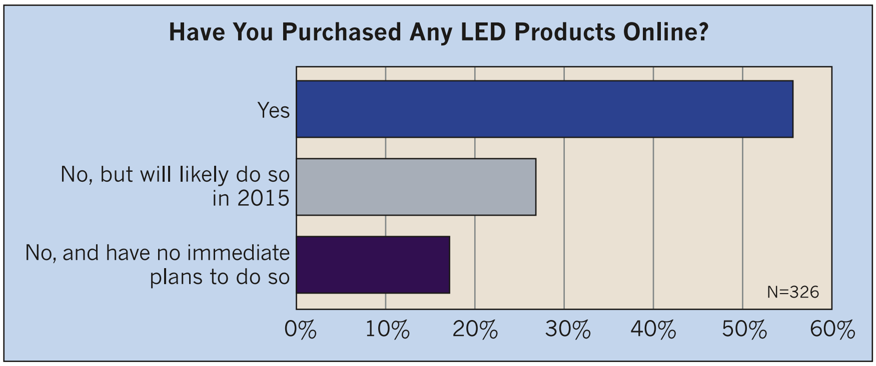


Fig. 1. More than half of *EC&M* survey respondents indicated they have purchased LEDs online, and more than a quarter said they plan to do so this year.

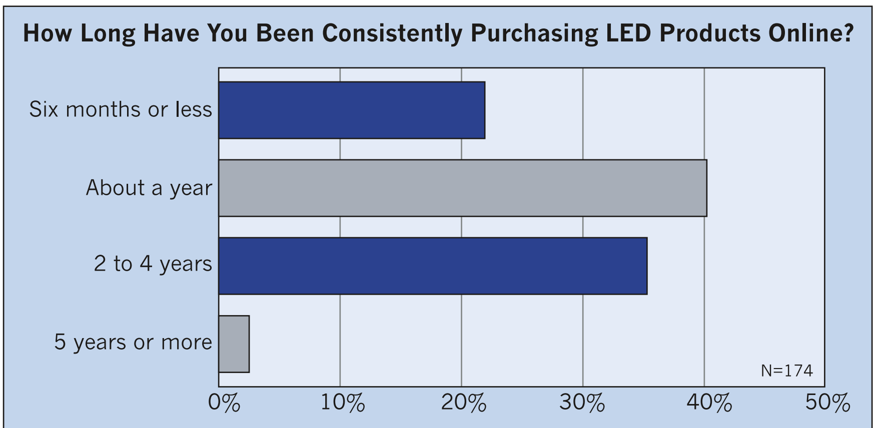


Fig. 2. The vast majority of respondents to an exclusive *EC&M* survey has been consistently purchasing LEDs online for the last four years or less.

Even as other established lighting technologies are refined and improved upon, LEDs have been anointed the clear leader in next-generation technologies that offer the best path forward in lighting. DOE says LED lighting sales based on lumen-hours are on track to account for 48% of all lighting sales by 2020, up from 3% in 2013. But as much as LED technology has improved and matured in recent years — and despite the impressive commercial inroads that have been made — it still holds mysteries on par with that of other newly introduced products, especially for contractors who haven't closely tracked its evolution. In many respects, the growing LED lighting market has a "Wild West" feel to it — where clear, objective quality standards have been slow to take shape, and buyers may lack the information needed to vet the quality, suitability, and reliability of products and suppliers.

That might not be readily evident, looking solely at the supply picture. Judging from their ample availability through a growing network of manufacturers and distributors, LED lighting solutions might be judged fully proven and reliably deployable. Easily purchased through numerous online channels, as well as through brick-and-mortar retailers and electrical products wholesalers, LED lamps, drivers, and controllers have an established and growing market presence that, when taken at face value, might instill confidence and certainty among buyers.

Instead, however, the ubiquity of LED products, despite a slow concentration of more power into the hands of fewer big sellers, may actually constitute a red flag of sorts for buyers. While the sellers' ranks are being culled some, the still-formative LED market is one marked by relative ease of entry. The door remains mostly open to suppliers peddling cheaper products of varying and even questionable quality and reliability, posing a very real threat to both uninformed buyers and even the growth trajectory of the LED market.

Factor in the persistent difficulty buyers have in assessing quality and intelligently comparing and contrasting products from different sources, and it's clear that the market for LED products more than ever demands discerning, educated, and fully engaged buyers. When those two realities collide in a developing and changing market — opportunistic sellers and many new, eager, and novice buyers — it's a recipe for confusion and dissatisfaction.

Simon Bratt/Hemera/Thinkstock

Nagging uncertainty. That's where many LED buyers find themselves today as they struggle with the core problem of uncertainty. Unsure of everything from expected real-world energy savings to the quality and power of the light to the reliability of the warranty, many still navigate the market tentatively, lacking the full confidence they're getting exactly what they and their customers need at the best price.

Peter Argyropolous, owner of Petros Electric, a Lancaster, Pa., contractor, regularly struggles to find the right LED solutions for clients. One of the big obstacles he faces is understanding the varying light quality of different products. His suppliers generally don't offer samples that would help him economically evaluate different alternatives. If they do, restocking fees come into play for returned products.

"There may be 50 options for under-cabinet lighting, but each produces a slightly different color rendering," he says. "I've seen it happen where an LED light is put in, and the kitchen countertops turn a puke green color under the light. Then the customer wants them ripped out. If I'm not able to show a sample, I can get myself in trouble."

An equally burdensome problem, he says, stems from the exclusive arrangements many suppliers maintain with manufacturers, whose product lineups can vary widely. If he's looking for an LED with certain specifications and his supplier's LED source doesn't make it, he's sometimes forced to go online in search of the product, which can amount to even more of a "crapshoot" scenario.

Some six years into the LED era, for example, buyers still struggle to understand how incandescent, HID, and compact fluorescent wattage values translate to LED products. Bill Wedge, owner of Wedge Electric, an Orange, Calif., contractor, says it's not as easy as it probably should be at this stage to find comparable output information. Some manufacturers provide such information; others don't.

"I think it should be more clear," he

says. "Each manufacturer should have an equivalency chart — something to gauge your light selection because a lot of times the LEDs are brighter than the standard lights you're replacing or that others are offering. Maybe there's an outdoor light, a wall-pack type fixture, and maybe the person has a 175W lamp in an existing HID light, and they want to go LED. A lot of the manufacturers may say something, for instance, is equal to a 250W or a 100W. Well, is there a direct replacement? If there's not a chart, give me a formula."

The online enticement. The challenge of fully understanding LED lighting ahead of purchasing isn't preventing buyers from taking their search into the online realm, where clear-cut answers may arguably be even harder to come by. A recent *EC&M* survey of 543 small electrical contractors' purchasing practices found that 56% of respondents who answered a specific question about online purchasing of LED products have actually done so (**Fig. 1** on page 18). An additional 27% said they haven't but are "likely" to do so in 2015. Only 17% said they had never bought online and had no plans to start. For respondents answering affirmatively to buying LEDs online, close to two-thirds indicated they'd only been doing so for a year or less (**Fig. 2** on page 18), while 36% noted they'd started this practice over the last two to four years.

One survey respondent, George Torres, owner of Chili Electric, Los Lunas, N.M., went the online route after he couldn't find satisfactory under-counter LED lighting for a customer or sufficient knowledgeable assistance through his local electrical suppliers. After an exhaustive search, he purchased LEDs, power supplies, and connecting hardware from an online vendor that turned out to be satisfactory.

"My local electrical houses have a limited amount of LED product; they're still looking to sell conduit and the wire and fittings; the trim stuff is a secondary concern," he says. "If they do have it, they're locked into a very narrow band of products. And, if you have questions, they're not trained enough to give you a detailed answer."

Torres ended up taking LED education into his own hands and soon realized it was a steep learning curve — one that was complicated by a lack of good go-to sources of information.

"It's like looking for a needle in a haystack that might be there, but until you ask the right questions and look in the correct spot, you won't find it," he says.

Contrary to his own reservations about buying LED products online, Tom Kristoff, owner of Kristoff Electric, Ravenna, Ohio, went that route when he needed to find LED lighting for a pool enclosure. Stymied in his efforts to find the product through

Market Mechanics Matter as Much as Good Buy

Success in the LED lighting installation business demands far more than just the ability to make smart product purchases. It increasingly requires a solid knowledge base that spans systems integration, the complex of incentives and rebates, and the future trajectory of lighting technology.

As LED lighting becomes a backbone of large-scale energy efficiency initiatives in buildings and other elements of the physical infrastructure, contractors' broader technical know-how in the areas of control systems, feedback sensors, building information systems, digital interfaces and connectivity, and system commissioning will come into play.

"On top of their other responsibilities, electrical contractors will be called on to ensure that systems are programmed correctly, sensors are installed and aimed properly, and end-users understand how the system works," says Jim Brodrick, lighting program manager for the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy's Building Technologies. "As controls continue to expand, the electrical contractor's role will become even more critical."

Looking to the future, Bill Attardi, an energy efficiency consultant who follows the LED lighting industry as owner of Attardi Marketing, Colts Neck, N.J., can envision contractors being challenged to understand lighting's possible evolution into a vehicle for enhanced IP-based network control. Some form of LED, he says, will almost certainly be the favored lighting type.

"When you talk about networking and the 'Internet of things' — where lighting can be the core connector to all the activity in a plant or commercial establishment and where you can connect a thermostat or HVAC system through the lighting — then all of a sudden people are looking at it and saying, 'since we have a luminaire in every room, we can put a camera or a sensor or a software package in there and get information out of the lighting system that we never even thought of,'" he says.

For now, though, what end-users want most of out their LED lighting systems is tangible, immediate, and practical: enhanced lighting quality and energy savings at a reasonable price. While an enhanced portfolio of technical skills will be clearly essential, contractors in the LED space will also have to be intimately familiar with the nuances of the many programs and platforms available to defray the customer's cost of lighting upgrades and retrofits and entice them to make the investment, says Bernie Erickson, Northeast regional manager for lighting contractor, Facility Solutions Group, Austin, Texas.

"Rebates drive so much of this work, but this can be a confusing area for contractors," he says. "If someone in the LED space is more informed and keeping up on what's happening with utility and other third-party rebates, and you're not, you can be at a real disadvantage. This is an area that requires a tremendous housekeeping effort and the ability to stay on top of the necessary homework."

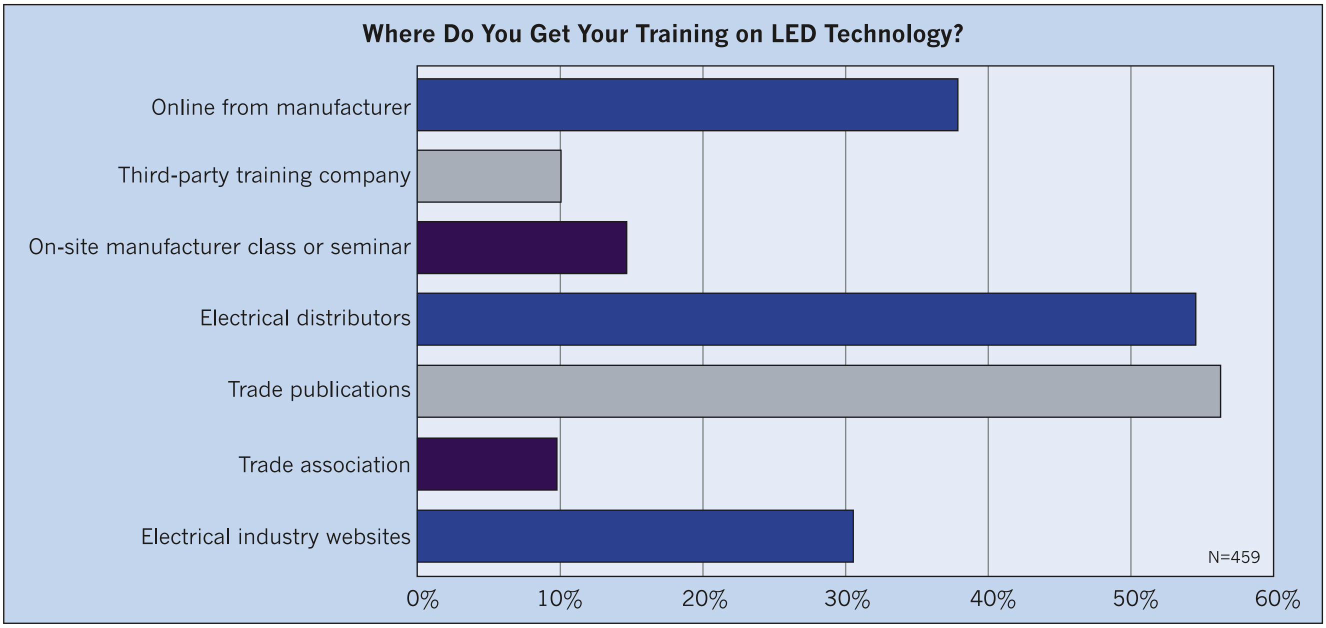


Fig. 3. When it comes to receiving training on LED technology, respondents were mixed in their sources.

his local suppliers, he found the special 2-foot LED fixture he needed through an online supplier.

"My local suppliers don't stock a lot of LEDs for unusual applications like this, so I sometimes have to shop online," he says. "Generally, though, I don't buy online because I want to stick with brands I know and trust. People are calling me all the time trying to sell me LED products, but I don't know who they are."

Search for answers. Given the growing number of products and manufacturers in the market and the emerging applications for LED lighting, Kristoff says he'd like a supplier base that could offer better selection. Equally valuable, he says, would be general information on LED lighting products and applications.

But such on-site training and education, perhaps sponsored by manufacturers,

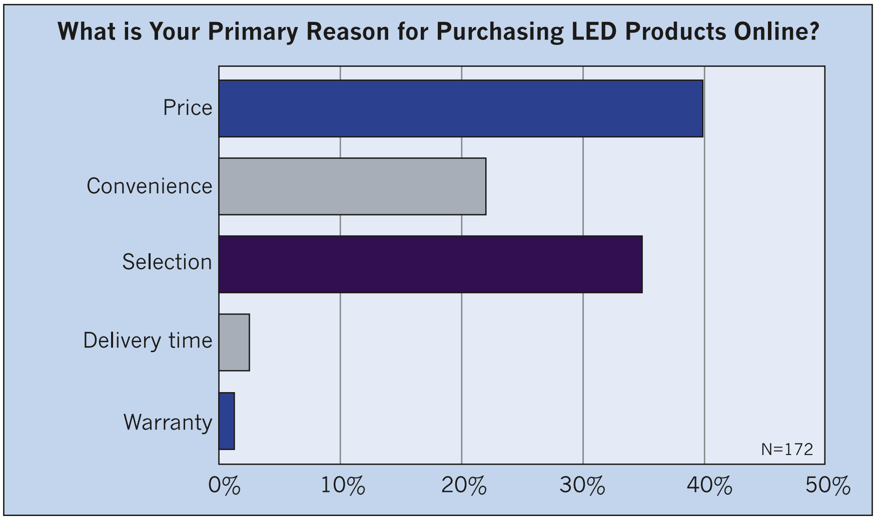


Fig. 4. Although price topped respondents' list as the primary reason for purchasing LEDs online, selection came in a close second.

is not presently a prime source of LED information for most contractors (**Fig. 3** on page 22). Only 15% of the contractors surveyed by *EC&M* said


Enough light to flood a dam.
Replace 1000W metal halide
with only 300W of LED.

they're getting their LED training from "on-site manufacturer classes/seminars." Only "trade associations" and "third-party training" were named by fewer respondents as sources. But contractors are looking to suppliers for information, only in different formats. Fifty-four percent included "electrical distributors" as a source of information, second only to "trade publications" in mentions. "Online from the manufacturer" was marked by 38%, while 31% identified "electrical industry web sites" as sources of information, suggesting the online realm, in general, is a fairly trafficked destination for contractors hunting for LED knowledge.

But the steady emergence of an online marketplace for LED lighting is being driven by the same practical considerations that drive contractors' general purchasing behavior. Knowledgeable or not, contractors are looking to online sources simply because they see them as a source of prospective value. Of 172 contractors who replied to the survey question about their prime motivation for online LED product purchasing, "price" was identified by the most at 40% (**Fig. 4** on page 24). "Selection" was the prime reason for 35%, while "convenience" was the top reason for 22%. Far down the list were delivery time and warranty considerations.

As alluring as the online marketplace can be for LED buyers, it holds more than a few pitfalls, especially for the uninitiated. Those low online prices so many apparently seek can mask issues of quality, suitability, and warranty protection that can come into play if a buyer lacks up-front knowledge.

Those cautions hold true for offline purchases as well, but the ease of buying online may amplify those concerns. Sources of supply are extensive and varied, spanning lighting specialists, Big Box retailers, and general merchandise vendors. Of seven sites listed in the *EC&M* survey, more selected Econolite.com (50%) and Amazon.com (39%) as preferred web sites for purchasing (**Fig. 5**). The Home Depot's site came in with 27%; 1000bulbs.com was identified by 21%; and the Lowe's site was named by 17%. Fastenal and Grainger were named by the fewest respondents.

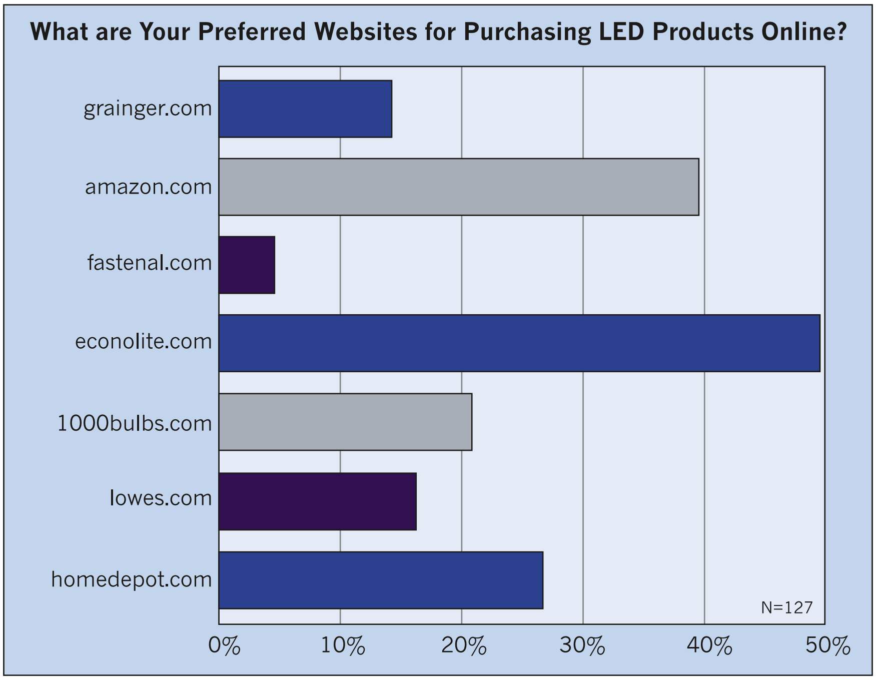


Fig. 5. Several industry websites were preferred by respondents, with www.econolite.com leading the pack.

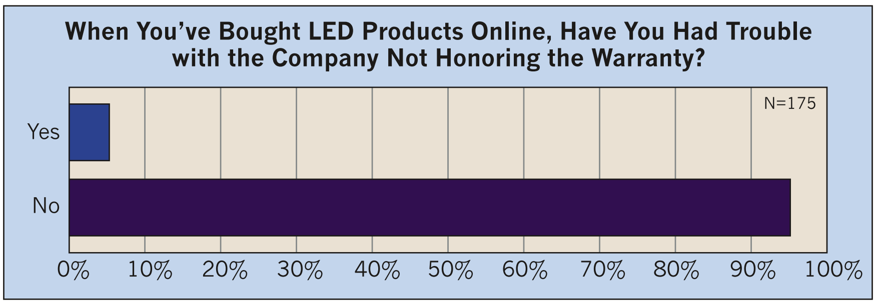


Fig. 6. Nearly all of respondents indicated that they had not had trouble with Internet suppliers honoring the warranty on LED products they purchased online.

The buyer's challenge. The DOE's LED lighting guru, Jim Brodrick, lighting program manager for the agency's Office of Energy Efficiency and Renewable Energy's Building Technologies, says LED lighting, despite its steady rise, remains a challenging area for many buyers.

The flip side of extensive and growing availability of LED products and falling prices is the disconcerting ease of choosing the wrong product, either for the specific application or as measured by various quality factors.

"It's very difficult to distinguish the low-cost, poorly designed luminaire from the more expensive product that offers excellent performance," Brodrick says. "The contractor must understand the technology sufficiently to be able to convince the facility manager or building owner why the least expensive LED luminaire is often not the best."

The two most important considerations that LED product buyers have today, he says, are matching the right product to the application and making certain they can rely on the supplier for service and support (see **Market Mechanics Matter as Much as Good Buy** on page 20). That holds true whether product is bought online or at a brick-and mortar-outlet, but the more shadowy online environment can leave buyers more exposed.

Bernie Erickson, Northeast regional manager for lighting contractor Facility Solutions Group, Austin, Texas, says with so many suppliers clamoring to bring LED products to market it pays to be wary.

"I get tons of blast emails every day from no-name companies saying 'buy my lamp for X number of dollars,'" he says. "They're trying to beat everyone down on price, but they may be rushing product to market. Many companies offering 10-year warranties have only been in business two years."

Yet the *EC&M* survey found that online LED buyers don't seem to be having bad experiences with product support, narrowly defined. Of 175 contractors responding to a question about warranties, 95% said they've had no trouble with online sellers honoring the warranty on products (**Fig. 6** on page 26).

When asked what types of LED products they purchase online, 98% named lamps, 41% indicated drivers, and 25% selected controllers (**Fig. 7**). Out of 26 product categories presented, not surprisingly, survey respondents were far

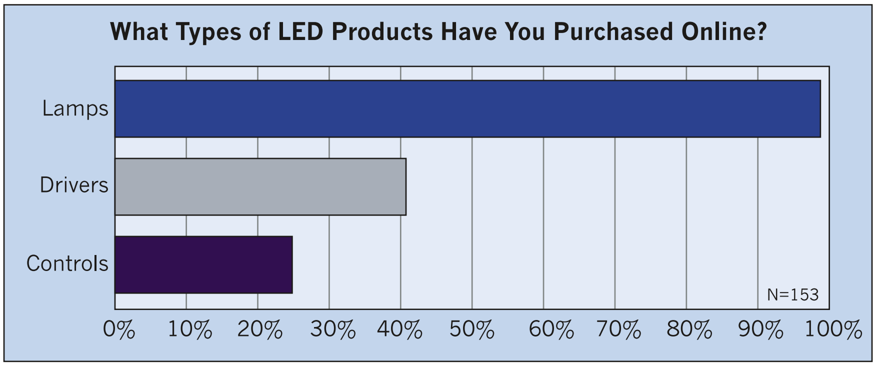


Fig. 7. Lamps were far and away the leading product contractors bought online, followed by drivers and controls.

and away most likely to buy luminaires (62%) than any other electrical product (**Fig. 8** on page 28).

Online sourcing has opened up new opportunities for discriminating LED buyers, but its use may skew toward price-conscious smaller contractors starting to dabble in the market or those willing to throw the dice on a deeply discounted product. For larger contractors deriving substantial revenue from large-scale lighting installation or retrofit projects, the main sources of supply may be traditional distribution channels or manufacturer-direct arrangements.

Jim Totzke, executive vice president

of operations at Menasha, Wis.-based electrical contractor, Faith Technologies, Inc., says the company now buys LED lighting products from just a few proven sources. Over time, the company's lighting retrofit group has identified suppliers who can best meet their needs on a range of measures. They've produced solid relationships that yield attractive pricing, timely product deliveries, and opportunities to stay on the cutting edge of LED product development.

"We're to the point now where we have made relationships with suppliers that we know we can trust with this product," Totzke says. "Having someone you can rely on to get you the fixtures, ballasts, and other components you need exactly when you need them is vital in our industry." **EC&M**

Zind is a freelance writer based in Lee's Summit, Mo. He can be reached at tomzind@att.net.

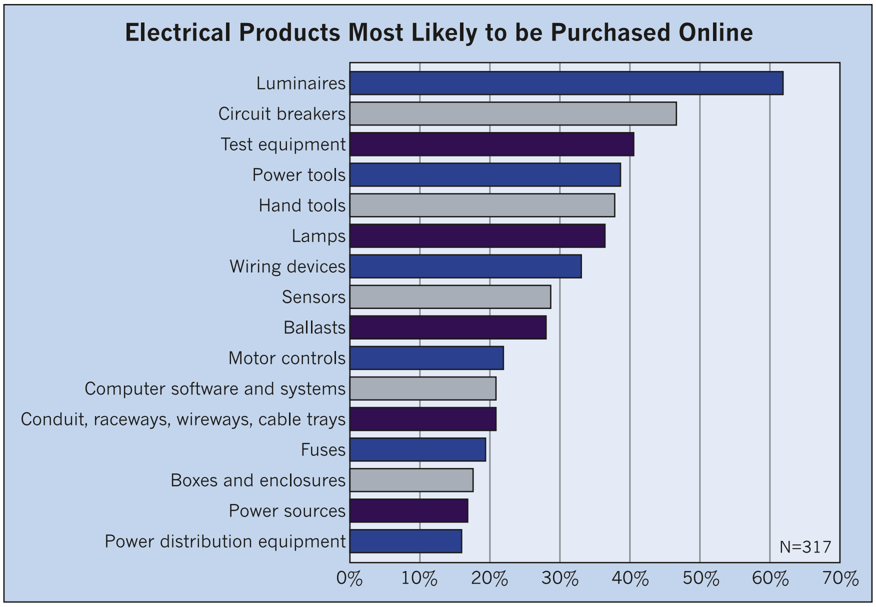
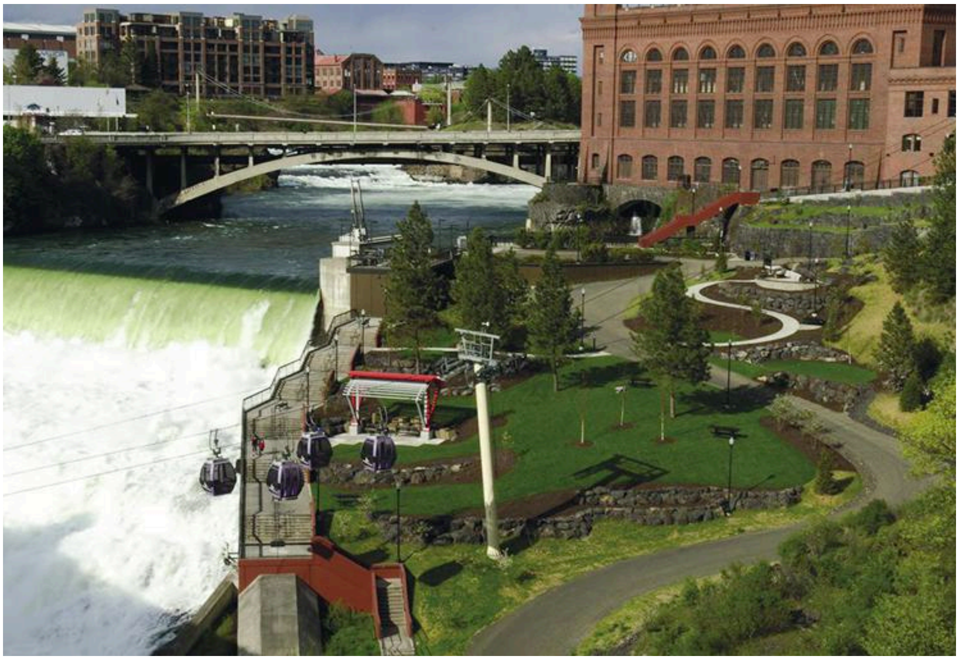


Fig. 8. Out of 26 product categories, contractors were most likely to purchase luminaires (62%) online, followed by circuit breakers (47%) and test equipment (40%).

Uncovering the Cost Benefits of a Good Lighting Circuit Design

Why you should beware of simplistic voltage drop calculations.



Parks such as Spokane, Wash.'s recently renovated Huntington Park on the Spokane River extends down the hillside, which places lighting poles along a meandering path — far from the source of electricity. In cases like this, precise voltage drop calculations are critical.

By Aaron Hesse, P.E., Coffman Engineers

Iterative voltage drop calculations are some of the most tedious and time-consuming components of an electrical design process. This is especially true for large lighting installations, such as those found in parks and parking lots as well as roads and highways. As a result, it is common for designers to oversimplify voltage drop calculations in a lighting design. With the lighting industry trending toward LED use, it is becoming increasingly common to string large quantities of luminaires on a single circuit due to the decreased load per luminaire. Now more than ever, detailed voltage drop calculations can avoid over engineering of lighting systems and substantially decrease project costs.

Guides and online calculators are readily available for little or no cost, many of which are based on IEEE Standard 141-1993, *Recommended Practice for Electric Power Distribution for Industrial Plants*. In Chapter 3.11 of this standard, voltage drop calculations and formulas are outlined in great detail. This standard, however, does not address voltage drop over long strings of loads. It is written primarily for a situation where a single load is energized at the end of a long feeder. However, this standard and the tools based on it are often inappropriately applied to voltage drop calculations of lighting systems.

Although the actual mathematics of the voltage drop calculation are beyond the scope of this article, it's important to keep in mind these calculations will reveal some complexities beyond Ohm's law. For example, voltage drop depends on the reactance of the conductor, the type of conduit surrounding the conductor, the power factor of the served load, and the temperature of the conductors during operation.

Lighting project example. On many projects, it often becomes necessary to branch out perpendicularly from a single string of luminaires rather than run along a fairly straight and long line. The lighting layout in Spokane's Huntington Park (see **Photo**) is a good example of this type of arrangement. The one-line diagram for this specific project (**Fig. 1**) resembles a tree shape. However, not all designers will

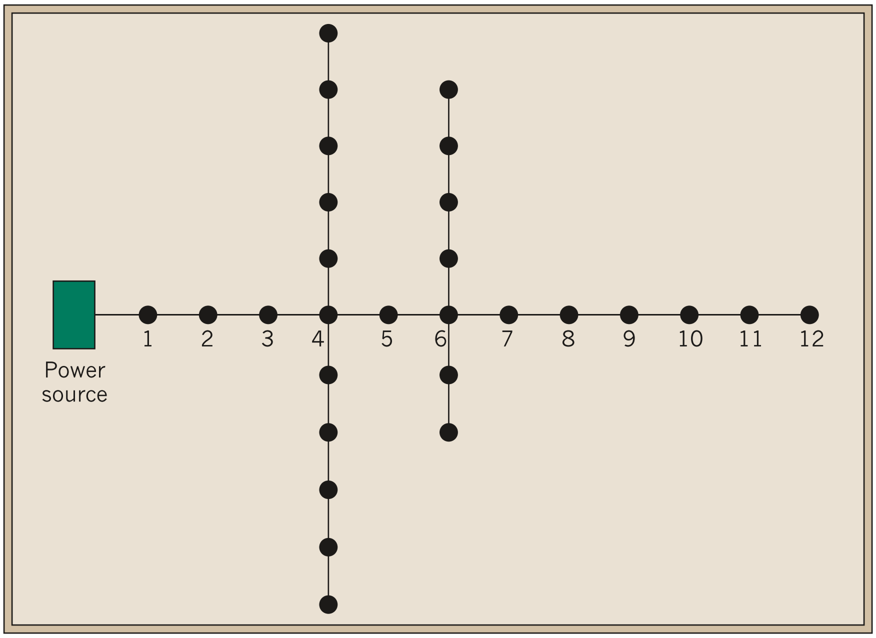


Fig. 1. Shown is a simplified one-line diagram of light pole connections in a Spokane, Wash., park.

approach sizing the required conductors in the same way. If the designer is still using traditional rules of thumb, the result could add significant cost to the project. Let's assume the following with regard to this particular project:

- The average distance between luminaires is 50 ft.
- Each pole-mounted LED luminaire consumes 178VA.
- The power factor is 1.00.
- The feeder uses Schedule 40 PVC.
- I^2R losses in the conductors are ignored.
- The available voltage at the source panel is 277VAC.

The one-line diagram in **Fig. 1** is often mistakenly modeled as shown in **Fig. 2**. To quickly size the required conductor in this example, a designer might perform the following calculation:

- Determine the total load on the circuit.
- Determine the branch with the longest distance from the source.
- Determine the design characteristics of the installation (such as those in **Table 1** on page 35).

Using the findings from the above steps, determine the required conductor size.

Running through this exercise will yield a result of two 4 AWG conductors and a 4 AWG ground in a 1 in. Schedule 40 PVC conduit. Note that the equipment grounding conductor increases are

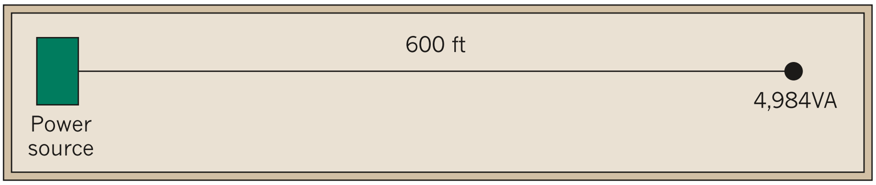


Fig. 2. Here, the one-line diagram from Fig. 1 is being modeled as a single-point load.

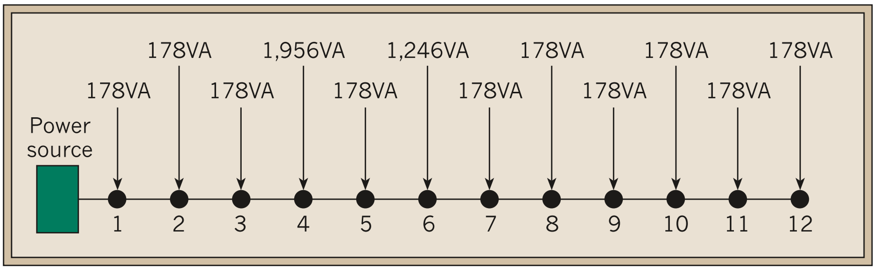


Fig. 3. This one-line diagram models the lighting load on the circuit using a "node" approach.

Voltage Drop Basics

Ohm's law states the relationship between voltage, current, and resistance. Given a constant current, voltage will drop a fixed amount when the current passes through a material with a fixed resistance. Generally, the served loads have far greater power consumption than the conductors serving them. However, given enough distance and enough current, the resistance found in conductors will cause the voltage to drop a significant amount over the length of the conductor.

Conductor resistance is generally expressed as a fixed impedance for every unit of distance (i.e., impedance per foot). This data is published in NFPA 70, the *National Electrical Code*. Using the tables found there, a designer can calculate the total impedance over the length of a standard size conductor. Referencing an industry standard such as IEEE Standard 141-1993, *Recommended Practice for Electric Power Distribution for Industrial Plants*, will provide the necessary formulas and procedures for a proper voltage drop calculation over a segment of wire.

NFPA 70 does not address voltage drop recommendations directly. Instead, it includes informational notes that describe the recommended voltage drop limits for general installations. A maximum of 5% total drop, including the source panel's feeder and no more than 3% for individual branch circuits, is recommended. Although not a fire hazard, exceeding this amount will result in poor performance and decreased equipment lifespan.

proportionate to the phase conductors per the requirements of Sec. 250.122(B) of the NEC. With a calculated voltage drop of approximately 2.3%, this installation will be Code compliant, meet desired design requirements, and adhere to IEEE Standard 141-1993 requirements.

This calculation can be performed in under an hour and doesn't require expensive software to yield an acceptable result. There are, however, numerous flaws with this approach, and more sophisticated approaches to this calculation will save the owner of this installation a substantial amount of money during construction.

Sizing with precision: the "nodal" model. The above method was sufficiently accurate in situations where only a few luminaires are placed on a single circuit. But as the number of luminaires on the circuit increases, the result of such a simplistic calculation deviates increasingly from reality. This is primarily due to the fact that the load on a segment increases as you approach the source — a factor ignored by this model. The first segment out to the first luminaire carries substantially more load than the segment near the end of the string.

Phase	Single
Conductor	Copper
Conduit	SCH 40 PVC
Voltage	277
Max voltage drop	3%
Length of run	600 ft
Total load	4,984VA

Table 1. Design characteristics of conductor run serving the park luminaires.

In order to properly model the example above, the designer must treat each load as a "node" and run a voltage drop calculation for each segment between nodes. Where a node has multiple branches, the longest branch should be selected first, and that node should be treated as a single node with the sum of all the loads on the unused branches. This can be seen in **Fig. 3** on page 32. The longest string (ending with load 12) was selected, and all the loads at nodes 4 and 6 were consolidated into single large loads.

In **Fig. 3**, the string of luminaires can be separated into 11 segments. This will require 11 voltage drop calculations. The starting voltage for each segment will be the end voltage of the previous voltage drop calculation. **Table 2** on page 38 summarizes the cumulative loads found in each segment

	Cost of Installation	Cost Savings	Percent Savings	Design Time (hr)	Design Cost ($98/hr)
Method 1	$24,088	0	-	1	$98
Method 2	$17,353	$6,735	28%	8	$784
Method 3	$13,424	$10,664	44%	10	$980

Table 3. Here is a cost summary of the three different design approaches outlined in this article.

and the resulting voltage drop.

The simplest approach to sizing the wiring at this point is the guess-and-check method. Assume a conductor size, run through the voltage drop calculations, adjust the wire size (as necessary), and repeat. The overall voltage drop for the feeder will be the total of all voltage drops calculated. It can be assumed that the consolidated unused branches, such as the branches on nodes 4 and 6, will have a voltage drop less than the calculated voltage drop due to the decreased distance and load.

Some designers choose to build complicated spreadsheets or use expensive modeling software. Regardless of the method, it becomes clear early in the process that this will require substantially more effort than the simple method outlined in the previous section. However, as you'll see, it's well worth the effort.

Using this approach will yield a result of two 8 AWG phase conductors and an 8 AWG ground conductor in a ¾-in. Schedule 40 PVC conduit. Again, with a calculated voltage drop of approximately 2.79%, the design achieved the same design goals and meets the same Code requirements as the previously described method.

Stepped conductor sizes. The previous two approaches make the assumption that a single conductor size will be used for the entire installation. To take the nodal method one-step further, a designer may wish to size each segment separately in order to achieve even greater cost savings to the project. However, it is important to keep in mind that for some projects, requiring many different wire sizes may cost more than choosing two or three. For example, in smaller installations, it may be less cost effective for a contractor to bring many wire sizes on-site — each with a minimum ordering quantity that is much greater than the required length.

Therefore, a reasonable balance must be found. Using the example from above,

From	To	Load (VA)	Segment Voltage Drop	Cumulative Voltage Drop	V_{START}	V_{END}
Source	Node 1	4,982	0.5%	0.5%	277.0	275.6
Node 1	Node 2	4,804	0.5%	1.0%	275.6	274.2
Node 2	Node 3	4,626	0.5%	1.5%	274.2	272.9
Node 3	Node 4	4,448	0.5%	1.9%	272.9	271.7
Node 4	Node 5	2,492	0.3%	2.2%	271.7	271.0
Node 5	Node 6	2,314	0.2%	2.4%	271.0	270.3
Node 6	Node 7	1,068	0.1%	2.5%	270.3	270.0
Node 7	Node 8	890	0.1%	2.6%	270.0	269.8
Node 8	Node 9	712	0.1%	2.7%	269.8	269.6
Node 9	Node 10	534	0.1%	2.7%	269.6	269.4
Node 10	Node 11	356	0.0%	2.8%	269.4	269.3
Node 11	Node 12	178	0.0%	2.8%	269.3	269.3

Table 2. Here's a summary of the cumulative voltage drop calculations for each segment of the lighting system shown in Fig. 3.

consider finding what appears to be the "trunk" of the system. This will be the area where the majority of the current will be carried. The most effective place to have an altered conductor size will be in this area. Leaving that conductor large and decreasing the conductor size in the less heavily loaded branches will allow for the most effective gains. Node 6 in **Fig. 1** is the last node with branches and could represent the end of the "trunk". For example, 8 AWG wire could remain in segments 1 through 6, and 10 AWG wire could be used for all the remaining branches. The resulting voltage drop over the branch circuit will approach 2.98% but still remain within recommended design limits and Code requirements.

Cost benefit. The cost benefit of this detailed approach outweighs the cost of the designer's time by a significant margin. Estimating the cost of each installation provides some surprising results. Note that cost estimates were performed using the recently published conductor pricing, conduit, and labor pricing from the latest edition of RS Means, industry standard contractor overhead and profit, and a 10% margin of error.

Using the simple method of sizing conductors (Method 1), the installation would cost approximately $24,088. Using the "nodal" model (Method 2), and using a single conductor size, the installation would cost approximately $17,353. Using the "nodal" model with a stepped conductor sizing scheme (Method 3), the cost of the installation would be $13,424. The percent of cost savings of Methods 2 and 3 as compared to Method 1 is summarized in **Table 3** on page 36.

As you can see from these findings, the cost of the additional design effort is well worth the savings. In a large park, road, or highway lighting project — where branches of these type can be found numerous times throughout the design — the savings to the overall project add up quickly. **EC&M**

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The Basics of Conductor Sizing — Part 1

How do you select a conductor that won't melt?

By Mike Holt, NEC Consultant

Unfortunately, making the proper choices when sizing electrical conductors can get complicated. For one thing, the ampacity tables can be very confusing — especially if you don't understand the "why" behind them and the correction factors you will most likely apply when using them.

A key factor is impedance, which is the opposition to current flow. In DC circuits, we call it "resistance." Whenever current (I) flows through a conductor, the opposition (R) to current flow produces heat. We call this current resistance heating "IR heating."

If you increase the current flow, you get more heat. The increase in heating (for a given impedance) is directly proportional to the square of the current flow. A complicating factor is that as a conductor heats up, its impedance also increases.

To determine what size conductor is sufficient to safely carry a given amount of current, you must account for IR heating and for the ability of the conductor to dissipate this heat. The number of current-carrying conductors in raceway affects dissipation ability, as does the surrounding temperature.

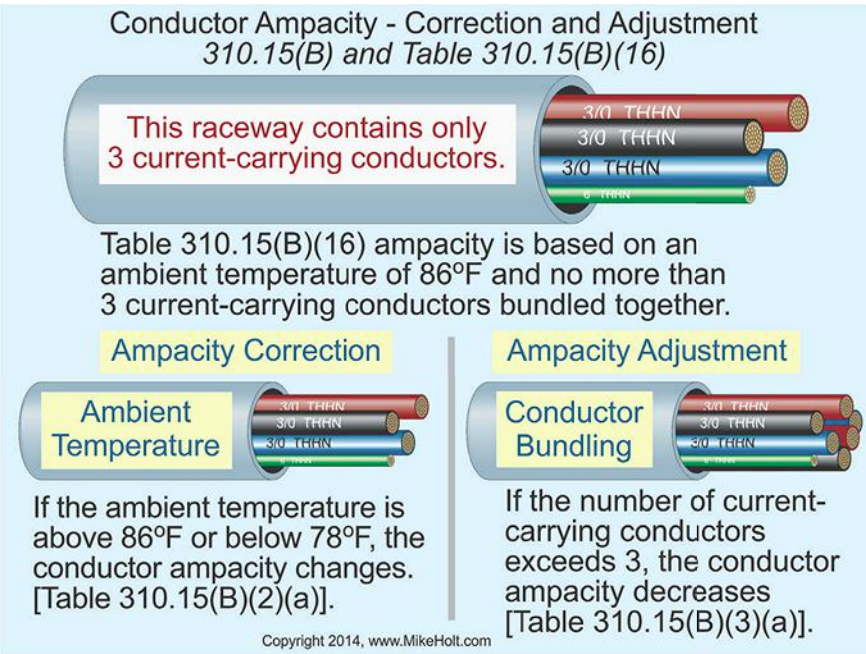

Fig. 1. Ampacity correction and adjustment factors are based on the ampacity rating of the conductor insulation per Table 310.15(B)(16).

Conductor heating. The temperature rating of a conductor is the maximum temperature (anywhere along its length) that the conductor can withstand over a prolonged period without experiencing serious degradation [310.15(A)(3), Note 1]. The main factors to consider for conductor operating temperature are:

- Ambient temperature.
- Heat generated internally from current flow through the conductor.
- The rate at which heat can dissipate.
- Adjacent load-carrying conductors.

If the conductor carries excessive current, then the IR heating within the conductor can damage the conductor's insulation or even melt the conductor itself.

The ampacity of a conductor is the maximum current a conductor can carry continuously, under the conditions of use, without exceeding its temperature rating. Table 310.15(B)(16) lists conductor ampacities under the condition of no more than three current-carrying conductors bundled together in an ambient temperature of 86°F (30°C). The reason for "no more than three" is because when you go above that number each additional conductor diminishes the heat dissipation abilities of all conductors in the raceway.

Ampacity correction and adjustment. Ampacity correction (ambient temperature) [Table 310.15(B)(2)(a)] and adjustment (bundling) [Table 310.15(B)(3)(a)] factors are based on the ampacity rating of the conductor insulation per Table 310.15(B)(16) (**Fig. 1**).

When determining conductor ampacity under the condition where the ambient temperature is not 86°F (30°C) or the

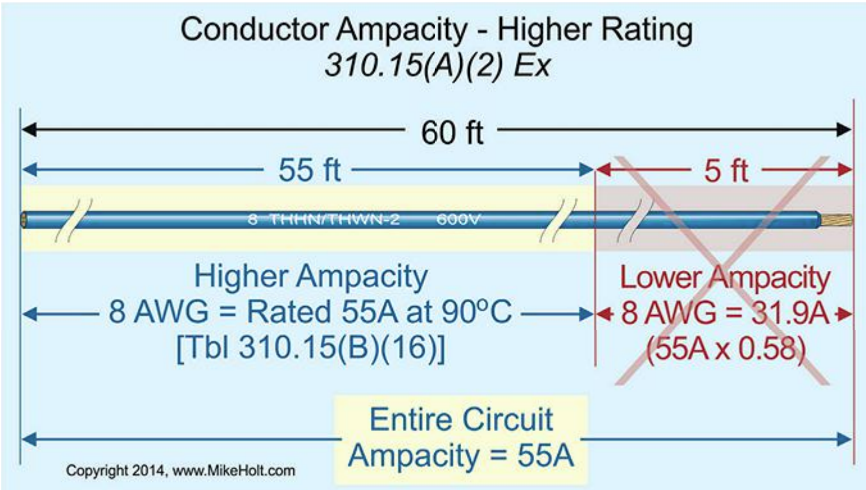

Fig. 2. When different ampacities apply, the higher ampacity is permitted for the entire circuit if the reduced ampacity length doesn't exceed 10 ft or 10% of the length of the higher ampacity, whichever is less.

raceway contains no more than three current-carrying conductors, we must use the ampacity listed in the 90°C column of Table 310.15(B)(16).

When conductors are installed in an ambient temperature other than 78°F to 86°F, you must use the multipliers listed in Table 310.15(B)(2)(a) to correct the ampacities listed in Table 310.15(B)(16).

The higher insulation temperature rating of 90°C rated conductors provides a greater conductor ampacity for use in ampacity correction and adjustment, even though you must size conductors based on the column that corresponds to the temperature listing of the terminals [110.14(C)(1)].

Where more than one ampacity applies for a given circuit length, you must use the lowest ampacity value [310.15(A)(2)]. But you can use a higher ampacity for the entire circuit if the reduced ampacity length doesn't exceed 10 ft or 10% of the length of the higher ampacity (whichever is less) [310.15.(A)(2) Ex] (**Fig. 2**). Here's the ambient temperature correction formula:

Corrected Ampacity = (Table 310.15(B)(16) Ampacity) × (Ambient Temperature Correction Factor [Table 310.15(B)(2)(a)])

Solving some example problems will help you see how this works.

<u>*Example Problem No. 1*</u>

What's the ampacity of a 12 THHN conductor installed in an ambient temperature less than 50°F (**Fig. 3**)?

The conductor ampacity for 12 THHN is 30A, at 90°C [Table 310.15(B)(16)]. The correction factor for a 90°C conductor installed in an ambient temperature of 50°F or less is 1.15 [Table 310.15(B)(2)(a)]. Therefore, we solve as follows: Corrected Ampacity = 30A × 1.15 = 34.40A Note that the ampacity increases when the ambient temperature is less than 30°C (86°F).

<u>*Example Problem No. 2*</u>

What's the ampacity of a 6 THWN-2 conductor when installed outdoors in an ambient temperature of 115°F?

The conductor ampacity for 6 THWN-2 is 75A, at 90°C [Table 310.15(B)(16)]. The correction factor for a 90°C conductor installed in an ambient temperature of 115°F is 0.82 [Table 310.15(B)(2)(a)]. Therefore, we solve as follows: Corrected Ampacity = 75A × 0.82 = 61.50A Note that the ampacity decreases when the ambient temperature is greater than 30°C (86°F).

<u>*Example Problem No. 3*</u>

What's the ampacity of 3/0 THHN conductors if the ambient temperature is 108°F?

The conductor ampacity for 3/0 THHN is 225A, at 90°C [Table 310.15(B)(16)]. The correction factor for a 90°C conductor installed in an ambient temperature of 108°F is 0.87 [Table 310.15(B)(2)(a)]. Therefore, we solve as follows: Corrected Ampacity = 225A × 0.87 = 196A.

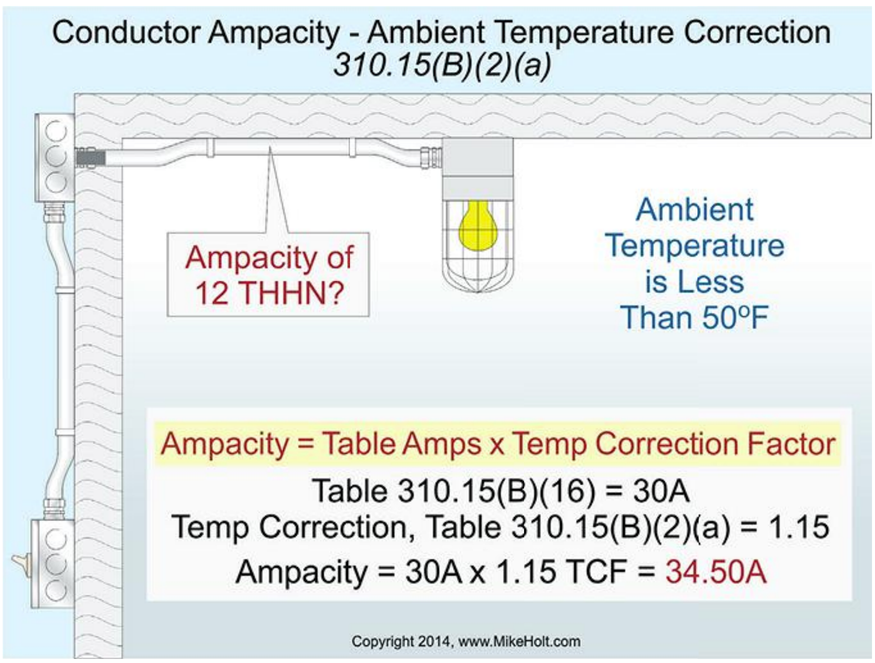

Fig. 3. The correction factor for a 90°C conductor installed in an ambient temperature of 50°F or less is 1.15.

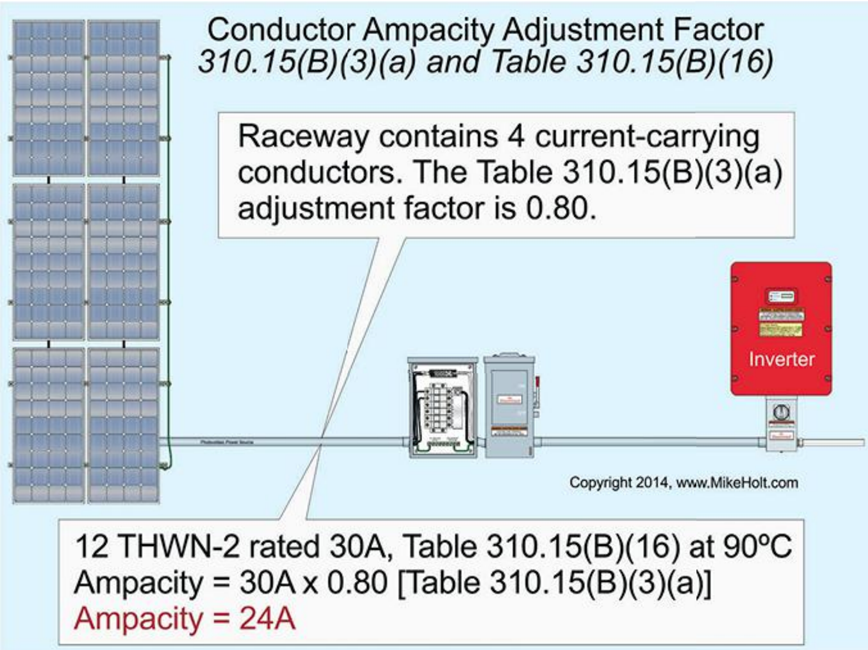

Fig. 4. The adjustment factor for four current-carrying conductors is 0.80.

Bundling adjustments. Bundling more than three conductors in the same raceway degrades the ability of each conductor to dissipate heat, requiring you to adjust the ampacity downward, accordingly.

Here's the conductor bundling adjustment formula:

Adjusted Ampacity = (Table 310.15(B)(16) Ampacity) × (Bundling Adjustment Factor [Table 310.15(B)(3)(a)])

Again, let's run through some example problems to show you how this works.

Example Problem No. 1

What's the adjusted ampacity of four 12 THWN-2 conductors in a raceway (**Fig. 4**)?

12 THWN-2 is rated 30A at 90°C [Table 310.15(B)(16)]. The adjustment factor for four current-carrying conductors is 0.80 [Table 310.15(B)(3)(a)]. Thus, the adjusted ampacity is calculated as follows: Adjusted Ampacity = 30A × 0.80 = 24A.

Example Problem No. 2

What's the adjusted ampacity of four 1 THWN conductors in a raceway?

1 THWN is rated 130A at 90°C [Table 310.15(B)(16)]. The adjustment factor for four current-carrying conductors is 0.80 [Table 310.15(B)(3)(a)]. Therefore, the adjusted ampacity is calculated as follows: Adjusted Ampacity = 130A × 0.80 = 104A.

Example Problem No. 3

What's the adjusted ampacity of 10 THHN conductors when nine current-carrying conductors are installed in a raceway or cable?

10 THHN is rated 40A at 90°C [Table 310.15(B)(16)]. The adjustment factor for nine current-carrying conductors is 0.70 [Table 310.15(B)(3)(a)]. Therefore, the adjusted ampacity is calculated as follows: Adjusted Ampacity = 40A × 0.70 = 28A.

The Table 310.15(B)(3)(a) adjustment factors apply only when you bundle more than three current-carrying conductors. Naturally, all phase conductors are considered current carrying, but what about other conductors?

When more than 30 current-carrying conductors are installed in any cross-sectional area of the wireway, you must use Table 310.15(B)(3)(a) to adjust the conductor ampacity listed in Table 310.15(B)(16) [376.22(B)].

The ampacity of a conductor is based on the "conditions of use" [100]. Table 310.15(B)(16) contains the allowable ampacities for insulated conductors, where no more than three current-carrying conductors are bundled together, based on ambient temperature of 30°C (86°F).

You must correct the allowable ampacity listed in Table 310.15(B)(16), if either:

- The ambient temperature isn't 86°F from Table 310.15(B)(2)(a).
- There are four or more current-carrying conductors bundled together per the factors contained in Table 310.15(B)(3)(a).

Staying neutral. These factors help determine if you should consider the neutral conductor to be a current-carrying conductor for ampacity adjustment [310.15(B)(5)]. The neutral conductor of a:

- 3-wire, single-phase, 120/240V system, or 4-wire, 3-phase, 120/208V or 277/480V wye-connected system, isn't considered a current-carrying conductor for conductor ampacity adjustment of 310.15(B)(3)(a) if it carries only the unbalanced current.
- 3-wire circuit of a 4-wire, 3-phase, wye-connected system carries about the same current as the line-to-neutral load currents of the other conductors and is considered a current-carrying conductor [310.15(B)(5)(b)]. In such a situation, one of the line-to-neutral currents isn't present and can be zeroed out of the neutral current formula.
- 4-wire, 3-phase, 120/208V or 277/480V wye-connected system is considered a current-carrying conductor for conductor ampacity adjustment [310.15(B)(3)(a)] if more than 50% of the neutral load consists of nonlinear loads.

And

- In two-wire circuits, the neutral and ungrounded conductors actually carry current — and you count both as current carrying.
- You don't count grounding and bonding conductors [310.15(B)(6)].

There's more. All of this seems like quite a bit of work just to size conductors, doesn't it? As we said at the outset, it's complicated. And it gets even more complicated because there are additional rules for feeders, taps, and branch circuits. We'll cover those in Part 2. **EC&M**

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Stumped by the Code?

By Mike Holt, NEC Consultant

All questions and answers are based on the 2014 NEC.

Q. How do we size the conductors and maximum overcurrent protection for an electric water heater? Please give an example.

A. An electric water heater having a capacity of 120 gal or less is considered a continuous load, for the purpose of sizing branch circuits [422.13]. Branch circuit conductors must have a rating of at least 125% of the ampere rating of a continuous load [422.10] and the overcurrent protection is sized to the requirements in Sec. 422.11(E)(3).

Branch circuit conductors must have overcurrent protection in accordance with Sec. 240.4, and the overcurrent device rating must not exceed the rating marked on the appliance [422.11(A)]. A typical water heater is considered a single non-motor-operated appliance and many of these don't have a marked overcurrent protection size. For non-motor appliances, the appliance overcurrent device must [422.11(E)]:

1) Not exceed the rating marked on the appliance, if not marked.

2) Not exceed 20A if the overcurrent device rating isn't marked, and the appliance is rated 13.30A or less, or

3) Not exceed 150% of the appliance rated current if the overcurrent device rating isn't marked, and the appliance is rated over 13.30A. Where 150% of the appliance rating doesn't correspond to a standard overcurrent device ampere rating listed in Sec. 240.6(A), the next higher standard rating is permitted.

Let's run through an example now to drive these points home.

What's the maximum size overcurrent protection device for a 4,500W, 240V water heater (**Fig. 1**)?

Protection Size = 4,500W ÷ 240V = 18.75A × 1.50 = 28A

Looking to the next size up, we would

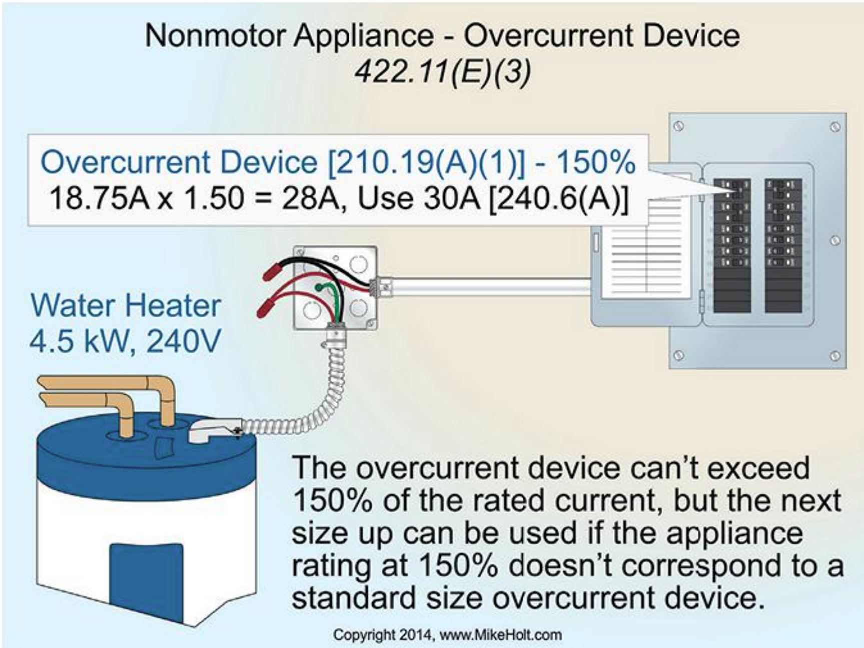


Fig. 1. Size an overcurrent protection device for a water heater per the steps noted in this figure.

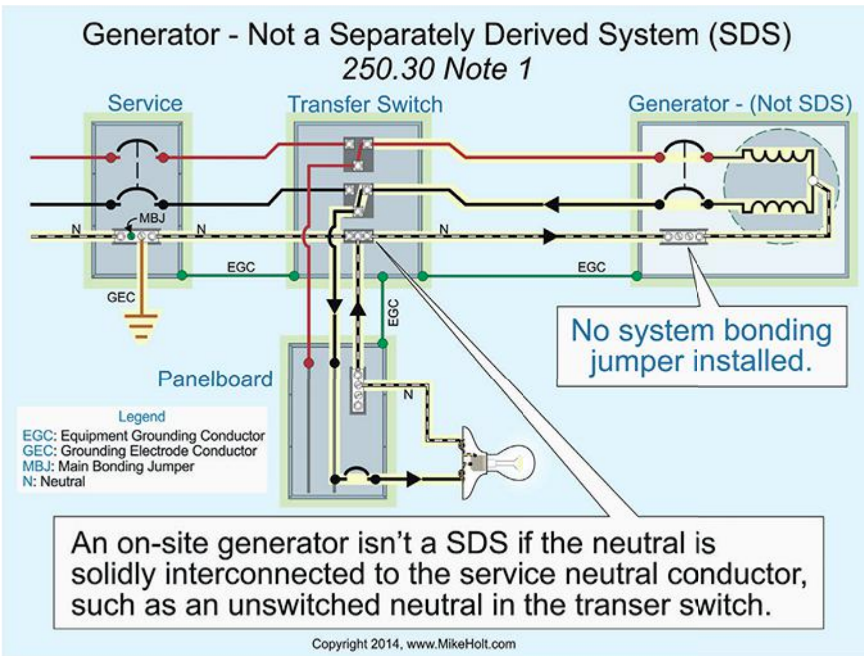


Fig. 2. See Art. 100 for a definition of a separately derived system.

choose a 30A device [240.6(A)].

Size the branch circuit conductors at 125% [422.10(A)].

Conductor Size = 18.75A × 1.25 = 23.4A

Referring to Table 310.15(B)(16), we see a 10 AWG conductor is rated 30A at 60°C.

Section 240.4(D)(7) required a 30A protection device for 10 AWG. Section 110.14(C)(1)(a)(1) directs us to the 60°C column of Table 310.15(B)(16) to match conductor sizing to terminal ratings.

Q. When is an on-site generator not a separately derived system?

A. An alternating-current power source such as an on-site generator isn't a separately derived system if the neutral conductor is solidly interconnected to a service-supplied system neutral conductor. An example is a generator provided with a transfer switch that includes a neutral conductor that's not switched [250.30 Note 1], as shown in **Fig. 2** on page 43.

According to Art. 100, a separately derived system is a wiring system whose power is derived from a source, other than a utility, where there's no direct electrical connection to the supply conductors of another system, other than through grounding and bonding connections.

Transformers are separately derived when the primary conductors have no direct electrical connection from circuit conductors of one system to circuit conductors of another system, other than connections through grounding and bonding connections.

A generator having transfer equipment that switches the neutral conductor, or one that has no neutral conductor at all, is a separately derived system and must be grounded and bonded in accordance with Sec. 250.30(A).

For non-separately derived systems, see Sec. 445.13 for the minimum size neutral conductors necessary to carry fault current [250.30 Note 2].

Q. What are the rules for sizing an equipment bonding jumper sized for parallel feeder circuits in a raceway?

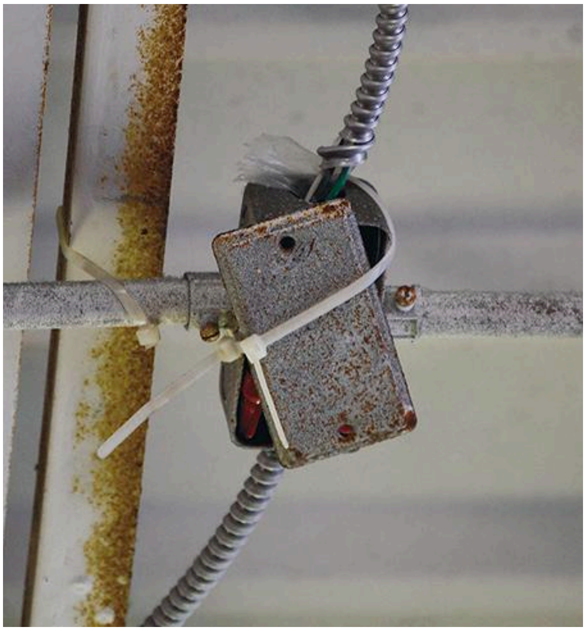
A. Bonding jumpers on the load side of feeder and branch circuit overcurrent devices are sized in accordance with Sec. 250.122, based on the rating of the circuit overcurrent device [250.102(D)]. For example, let's say you're working with metal raceway where the circuit conductors are protected by a 1,200A overcurrent device. A quick check of Table 250.122 reveals the minimum size bonding jumper needed is 3/0 AWG. It's also important to note that if a single bonding jumper is used to bond two or more raceways, it must be sized in accordance with Sec. 250.122, based on the rating of the largest circuit overcurrent device. **EC&M**

Illustrated Catastrophes

By Russ LeBlanc, NEC Consultant

All references are based on the 2014 edition of the NEC.

A WHOLE-LOTTA-WRONG



I'm not quite sure where to begin with this one because there is so much wrong. Perhaps the most dangerous violation is the way in which the MC cable is wired into this box. In violation of Sec. 330.30(A), the cable jacket was not cut cleanly and was just peeled back, leaving jagged metal edges in contact with the conductors. This could easily damage the insulation and cause a short circuit. The lack of a connector on the cable is also dangerous because there is no electrical continuity established between the metal box and the metal cable jacket. This lack of continuity is a violation of Sec. 300.10.

The use of EMT to support the box violates Sec. 358.12(5). Similarly, Sec. 314.23(E) has been violated because that section requires the use of conduit threaded wrenchtight into threaded entries or special hubs when supporting a box with a raceway. The misuse of a cable tie to support the EMT raceway is a violation of Sec. 110.3(B). Even its name indicates that "cable tie" is not the correct supporting means for a "raceway."

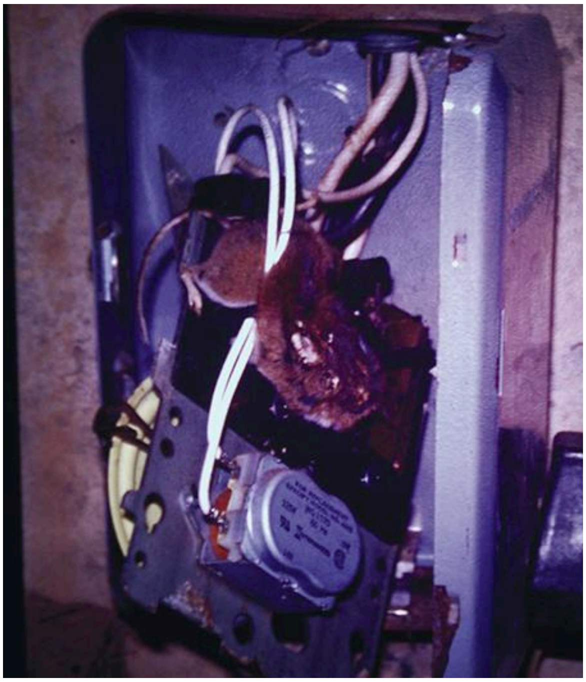
Lastly is the lackadaisical way in which the installer attempted to install a cover on the box, violating the intent of Sec. 314.25 in the process.

HICKORY, DICKORY, DOCK ...

This poor mouse had no idea of the danger lurking inside this time clock enclosure. I found him wedged behind the removable clock motor insert while I was on an emergency call troubleshooting the reason why some parking lot lights were not working. Needless to say, I found the problem.

The circuit breaker tripped when this poor guy came into contact with the energized contacts on the back of the time clock. He stood no chance of surviving. The reason he was able to get inside this enclosure was because one of the knockouts was missing and never closed up — a clear violation of the requirements of Sec. 110.12(A). It also created some safety concerns when the circuit breaker tripped, which plunged the busy parking lot into complete darkness. Thankfully, the presence of the mouse and the short circuit he caused did not lead to a worse situation, such as a fire caused by arcing and sparking.

In accordance with Sec. 110.12(B), I needed to replace the time clock because it was damaged. The installation of a simple and inexpensive knockout seal could have prevented this entire situation from happening in the first place.



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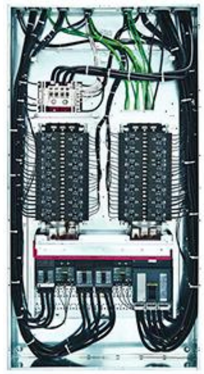

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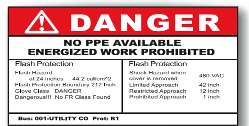

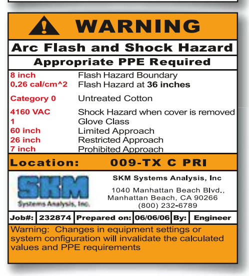

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What's Wrong Here?

By Russ LeBlanc, NEC Consultant

How well do you know the Code? Think you can spot violations the original installer either ignored or couldn't identify? Here's your chance moonlight as an electrical inspector and second-guess someone else's work from the safety of your living room or office. Can you identify the specific Code violation(s) in this photo? *Note:* Submitted comments must include specific references from the 2014 NEC.

Hint: Exposure disclosure

'TELL THEM WHAT THEY'VE WON...'

Using the 2014 NEC, correctly identify the Code violation(s) in this month's photo — in 200 words or less — and you could win an Arlington Industries FLBR101MB Non-Metallic Floor Box with Metal Cover. E-mail your response, including your name and mailing address, to neccodeguy@hotmail.com, and Russ will select three winners (excluding manufacturers and prior winners) at random from the correct submissions. Note that submissions without an address will not be eligible to win.

February Winners

Our three winners this month were: Brandon Tully, president of Skill Electric, LLC in Vincennes, Ind.; Mark Koester, an electrical estimator for RMF Nooter in Sylvania, Ohio; and Jean-Jacques Ahounou, P.E., an associate senior electrical engineer with Skidmore, Owings & Merrill LLP in Washington, D.C. Each of them correctly identified the Code violations shown in this outdoor luminaire installation.

In damp or wet locations, Sec. 314.15 requires boxes, conduit bodies, and fittings to be placed to prevent moisture from entering or accumulating inside. These boxes, conduit bodies, and fittings must also be listed for use in this wet location. Neither the "handi-box" nor the set-screw EMT connectors is designed for use in an outdoor wet location.

Section 314.29 requires the LB conduit bodies to be installed in a manner such that the wiring inside of them can be accessed without removing any part of the building or structure. Gaining access to the wires inside these conduit bodies would be impossible without smashing out some of the bricks or separating the raceways because the covers have been placed tight up against the brick walls. Lastly, Sec. 358.30(A) requires EMT to be securely fastened within 3 ft of each box or conduit body.

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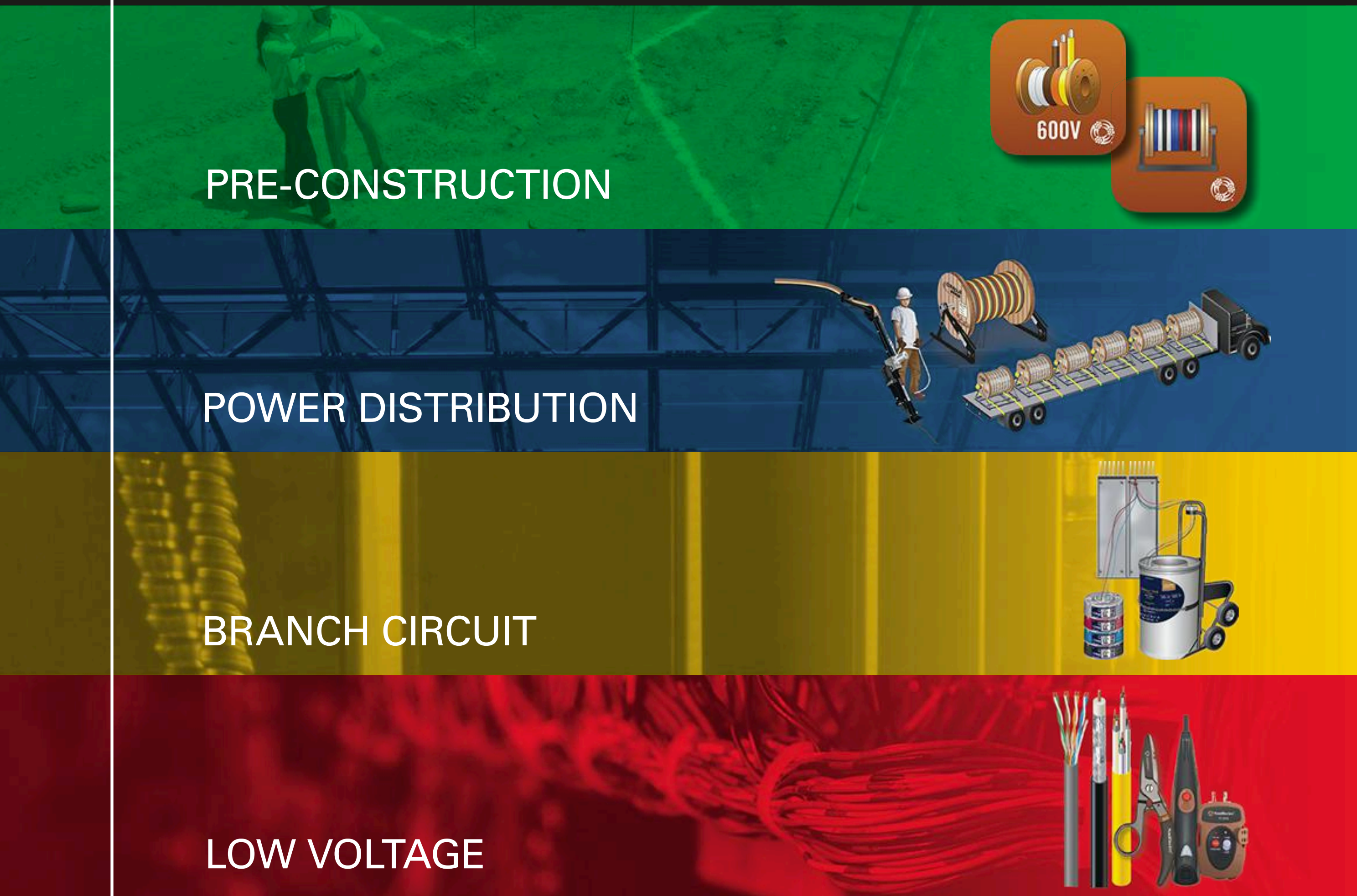

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