ELECTRICAL POWER SAFETY NEWS

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NETA®

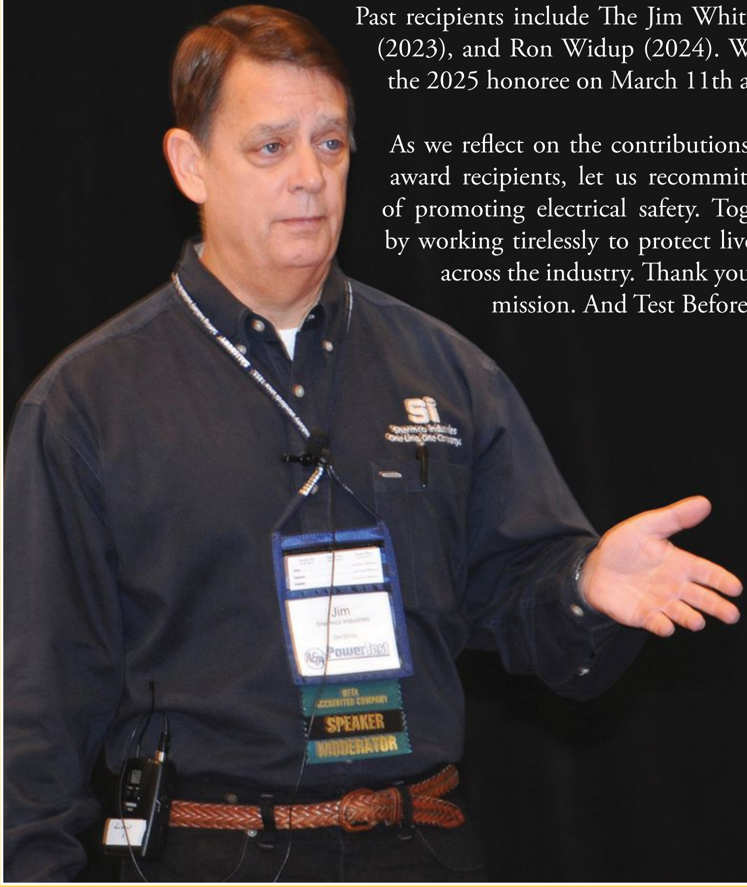
Welcome to the inaugural issue of NETA's *Electrical Safety* supplement, published annually with the Spring issue of *NETA World*. This special edition serves as a heartfelt reminder of the critical importance of electrical safety — a responsibility that touches every corner of our industry and impacts the well-being of countless lives.

We are honored to begin this issue with one of the final articles written by James R. (Jim) White, whose legacy continues to inspire us all. Jim's unmatched expertise, coupled with his humorous spirit and dedication to the education of technicians and working people everywhere, made him a guiding light in the field of electrical safety. Throughout his career, he impacted countless electrical workers with knowledge, instilling practical wisdom and an unwavering respect for the hazards of electricity. His teaching style was a distinctive blend of common sense, passion, and dry-wit humor that made learning from him not only impactful but unforgettable.

To honor Jim's memory and continue his mission, NETA established the James R. White Safety Award. This award is a tribute to individuals who embody Jim's spirit — those who, like him, demonstrate an extraordinary commitment to advancing electrical safety and protecting lives. Each year, the recipient is selected by NETA's Safety Committee and recognized during the PowerTest technical conference.

Past recipients include The Jim White Family (2022), Jim Dollard (2023), and Ron Widup (2024). We look forward to celebrating the 2025 honoree on March 11th at PowerTest25.

As we reflect on the contributions of Jim and these remarkable award recipients, let us recommit ourselves to the shared goal of promoting electrical safety. Together, we honor their legacy by working tirelessly to protect lives and create safer workplaces across the industry. Thank you for joining us in this essential mission. And Test Before Touch!



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ELECTRICAL POWER SAFETY NEWS

SPRING 2025

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The electrical power industry's information resource for electrical power standard updates, training, personal protective equipment (PPE), and the latest technology designed to improve electrical power system safety

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USING NFPA 70E TO DETERMINE SHOCK AND ARC FLASH BOUNDARIES

BY JAMES R. WHITE, *Shermco Industries*

The 2018 edition of NFPA 70E is still active, even though many people are looking forward to a new edition in 2021. The 2021 edition will be released to the public in late September or early October, first in pdf form, then as a printed document. Until that release, the current edition must be referenced.

SHOCK BOUNDARIES

Shock remains the number-one cause of electrical fatalities and has been for several years. Arc flash gets the most attention because of the serious injuries caused by an arc flash, not to mention the visual and audible results, which tend to be more impressive than a shock. After all, what electrician or technician hasn't been shocked at one time or another and just received a slight jolt, maybe a sting — and you look around to make certain no one was watching? We tend to think of low-voltage shocks as more of a nuisance then a real threat, but that is wrong-headed thinking.

Somewhere in the 1999–2002 range, an IEEE Electrical Safety Workshop presentation by Lanny Floyd and Danny Liggett of E.I. DuPont included Figure 1, which was the result of a study done at their facilities. Since these were industrial sites and not utilities, it's not surprising to see that the over-600 V range is only 11% of the fatalities. It is also not surprising that 250–600 V (mostly 480 V) is the largest percentage of fatalities at 45%. What is very surprising to most people is that 100–250 V is right next to it at 39%. Now, this was an old paper, but the percentages even now tell a real story about the risk involved in dealing with lower voltages.

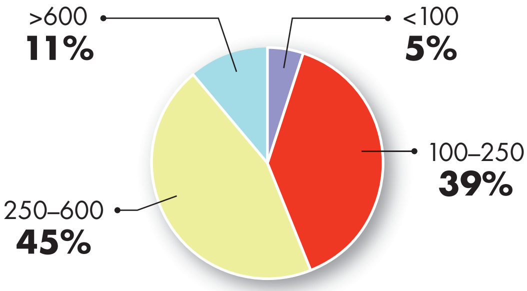

Figure 1: *Lethal Voltages at an Industrial Facility*
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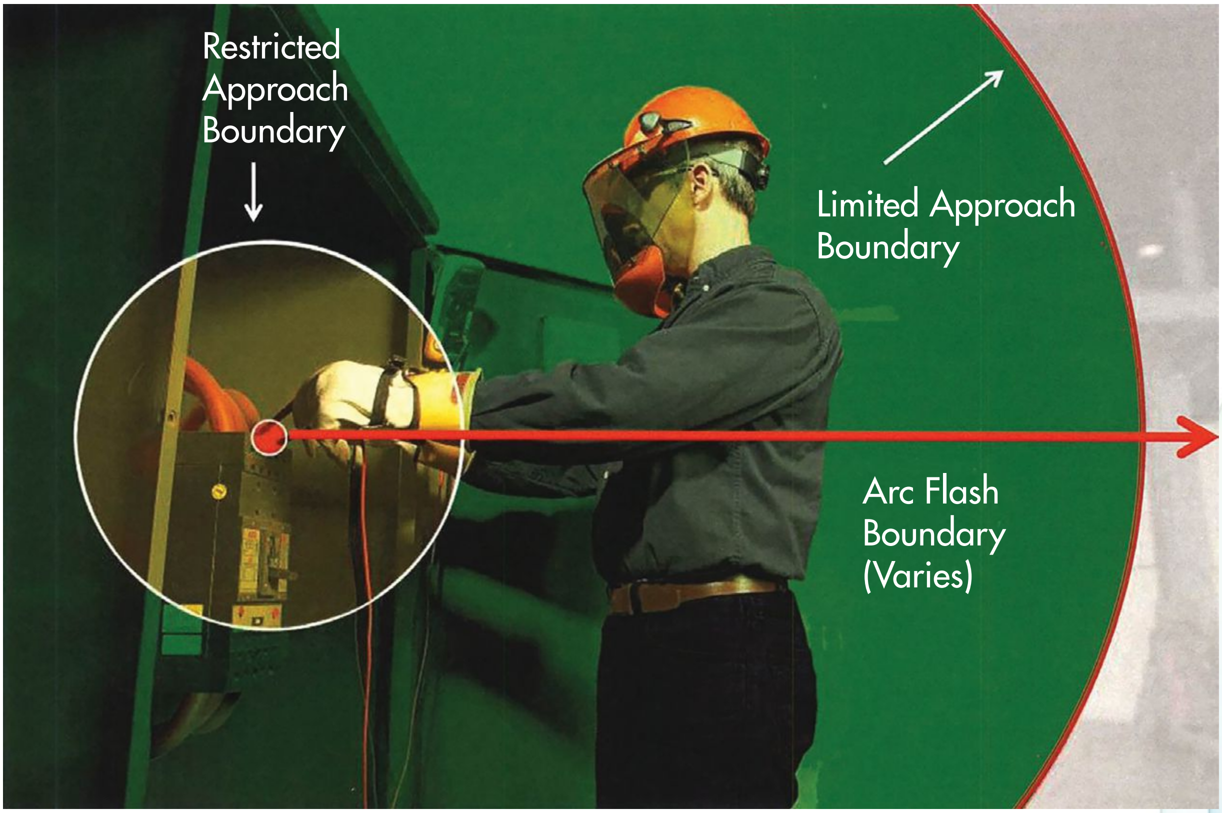
In NFPA 70E-2018, Article 130 Section 130.4 outlines the shock protection boundaries. But



before the tables, Section 130.4 Shock Risk Assessment states:

(A) General. A shock risk assessment shall be performed:
(1) To identify shock hazards
(2) To estimate the likelihood of occurrence of injury or damage to health and the potential severity of injury or damage to health
(3) To determine if additional protective measures are required, including the use of PPE

***N** (B) Additional Protective Measures. If additional protective measures are required, they shall be selected and implemented according to the hierarchy of risk control identified in 110.1(H). When the additional protective measures include the use of PPE, the following shall be determined:*
(1) The voltage to which personnel will be exposed
(2) The boundary requirements
(3) The personal and other protective equipment required by this standard to protect against the shock hazard

"N" indicates that a new section was added. 130.4(A) states the purposes of performing a shock risk assessment, while 130.4(B) provides the needed information concerning "additional protective measures" as provided in Section 110.1(H)(3). A quick look at that section shows use of PPE as the lowest priority, while placing the equipment in an electrically safe work condition (elimination) is highest. Due to issues that arose using standards from American National Standards Institute (ANSI) and American Industrial Hygiene Association (AIHA) in this particular application, it won't be carried over into the 2021 edition, although its intent will be. Elimination is always the first choice; PPE is the last, although using appropriate PPE is often unavoidable.

The other risk control methods listed in 110.1(H)(3) should be incorporated to the degree possible. It would be unsafe (and not too smart) to troubleshoot energized electrical conductors and circuit parts without using PPE. Troubleshooting increases the shock risk because if the equipment was in normal operating condition, per Section 110.2(A)(4), troubleshooting would not be necessary; the risk of arc flash also increases. The fact that equipment requires troubleshooting indicates it's at risk of failure. Not everyone catches that; it's just a normal day on the job — but it is not normal. More detailed information on the hierarchy of risk control methods is found in Informative Annex F.

The shock approach boundaries are easy enough to interpret from Table 130.4(D)(a) for AC voltages and 130.4(D)(b) for DC voltages. One key point to remember is that this table has two columns for the limited approach boundary. Column 2 is for exposed movable conductors, such as overhead power lines. It is also for when mechanical equipment is approaching an exposed conductor, movable or otherwise. Equipment tends to bob and sway, especially if the wind is blowing or the lift is extended. Another point to remember is that only qualified persons should approach overhead conductors unless they have been locked out/tagged and grounded. In industrial facilities, this often must be done by the local utility. Table 1 illustrates Table 130.4(D)(a); Table 2 illustrates 130.4(D)(b).

Bear in mind that these distances are approximated in the field. No one is going to take out their metal tape measure and try to be as accurate as possible.

Table 1: *NFPA 70E Table 130.4(D)(a)*

(1)	(2)	(3)	(4)
Nominal System Voltage Range, Phase to Phase[a]	**Limited Approach Boundary[b]**		**Restricted Approach Boundary[b]; Includes Inadvertent Movement Adder**
	Exposed Movable Conductor[c]	**Exposed Fixed Circuit Part**	
Less than 50 V	Not specified	Not specified	Not specified
50 V–150 V[d]	3.0 m (10 ft. 0 in.)	1.0 m (3 ft. 6 in.)	Avoid contact
151 V–750 V	3.0 m (10 ft. 0 in.)	1.0 m (3 ft. 6 in.)	0.3 m (1 ft. 0 in.)
751 V–15 kV	3.0 m (10 ft. 0 in.)	1.5 m (5 ft. 0 in.)	0.7 m (2 ft. 2 in.)
15.1 kV–36 kV	3.0 m (10 ft. 0 in.)	1.8 m (6 ft. 0 in.)	0.8 m (2 ft. 9 in.)
36.1 kV–46 kV	3.0 m (10 ft. 0 in.)	2.5 m (8 ft. 0 in.)	0.8 m (2 ft. 9 in.)
46.1 kV–72.5 kV	3.0 m (10 ft. 0 in.)	2.5 m (8 ft. 0 in.)	1.0 m (3 ft. 6 in.)
72.6 kV–121 kV	3.3 m (10 ft. 8 in.)	2.5 m (8 ft. 0 in.)	1.0 m (3 ft. 6 in.)
138 kV–145 kV	3.4 m (11 ft. 0 in.)	3.0 m (10 ft. 0 in.)	1.2 m (3 ft. 10 in.)
161 kV–169 kV	3.6 m (11 ft. 8 in.)	3.6 m (11 ft. 8 in.)	1.3 m (4 ft. 3 in.)
230 kV–242 kV	4.0 m (13 ft. 0 in.)	4.0 m (13 ft. 0 in.)	1.7 m (5 ft. 8 in.)
345 kV–362 kV	4.7 m (15 ft. 4 in.)	4.7 m (15 ft. 4 in.)	2.8 m (9 ft. 2 in.)
500 kV–550 kV	5.8 m (19 ft. 0 in.)	5.8 m (19 ft. 0 in.)	3.6 m (11 ft. 8 in.)
765 kV–800 kV	7.2 m (23 ft. 9 in.)	7.2 m (23 ft. 9 in.)	4.9 m (15 ft. 11 in.)

Notes:

(1) For arc flash boundary, see 130.5(A)

(2) All dimensions are distance from exposed energized electrical conductors or circuit part to employee.

[a] For single-phase systems above 250 volts, select the range that is equal to the system's maximum phase-to-ground voltage multiplied by 1.732.

[b] See definition in Article 100 and text in 130.4(D)(2) and Informative Annex C for elaboration.

[c] *Exposed movable conductors* describes a condition in which the distance between the conductor and a person is not under the control of a person. The term is normally applied to overhead line conductors supported by poles.

[d] This includes circuits where the exposure does not exceed 120 volts nominal.

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Table 2: *NFPA 70E Table 130.4(D)(b)*

(1)	(2)	(3)	(4)
Nominal Potential Difference	Limited Approach Boundary		Restricted Approach Boundary; Includes Inadvertent Movement Adder
	Exposed Movable Conductor*	Exposed Fixed Circuit Part	
Less than 50 V	Not specified	Not specified	Not specified
50 V–300 V	3.0 m (10 ft. 0 in.)	1.0 m (3 ft. 6 in.)	Avoid contact
301 V–1 kV	3.0 m (10 ft. 0 in.)	1.0 m (3 ft. 6 in.)	0.3 m (1 ft. 0 in.)
1.1 kV–5 kV	3.0 m (10 ft. 0 in.)	1.5 m (5 ft. 0 in.)	0.5 m (1 ft. 5 in.)
5 kV–15 kV	3.0 m (10 ft. 0 in.)	1.5 m (5 ft. 0 in.)	0.7 m (2 ft. 2 in.)
15.1 kV–45 kV	3.0 m (10 ft. 0 in.)	2.5 m (8 ft. 0 in.)	0.8 m (2 ft. 9 in.)
45.1 kV–75 kV	3.0 m (10 ft. 0 in.)	2.5 m (8 ft. 0 in.)	1.0 m (3 ft. 6 in.)
75.1 kV–150 kV	3.3 m (10 ft. 8 in.)	3.0 m (10 ft. 0 in.)	1.2 m (3 ft. 10 in.)
150.1 kV–250 kV	3.6 m (11 ft. 8 in.)	3.6 m (11 ft. 8 in.)	1.6 m (5 ft. 3 in.)
250.1 kV–500 kV	6.0 m (20 ft. 0 in.)	6.0 m (20 ft. 0 in.)	3.5 m (11 ft. 6 in.)
500.1 kV–800 kV	8.0 m (26 ft. 0 in.)	8.0 m (26 ft. 0 in.)	5.0 m (16 ft. 5 in.)

Note: All dimensions are distance from exposed energized electrical conductors or circuit part to worker.
**Exposed movable conductors* describes a condition in which the distance between the conductor and a person is not under the control of a person. The term is normally applied to overhead line conductors supported by poles.

SOURCE: NATIONAL FIRE PROTECTION ASSOCIATION

That was never the intent. If you're farther than the indicated distance, you're fine. Always try to leave a little extra.

Column 3 is for exposed fixed parts, such as installed equipment, which is what most of us work on. While column (2) and column (3) are the closest an unescorted, unqualified person can approach energized parts or conductors, column (4) is the restricted approach boundary, and only qualified persons can cross it. If you're not qualified, never cross the restricted approach boundary, and only cross the limited approach boundary if you are continuously escorted by a qualified person. The fact that a person is unqualified means they cannot determine energized parts from de-energized parts and/or cannot choose appropriate PPE. They are putting themselves and others at risk if they do.

ADDITIONAL PROTECTIVE MEASURES

Many people interpret the phrase "additional protective measures" as saying "use PPE." Section 130.4 refers the user to 110.1(H)(3), and that section refers the user to Informative Annex F Risk Assessment and Risk Control. A quick look at Informative Annex F shows Table F.3 The Hierarchy of Risk Control Methods. Unlike the main text in Section 110.1(H)(3), Table 3 provides some examples of each risk control method. More people should read through the Informative Annexes. They may be optional, but they often contain valuable information that gives more complete information than can fit into the main text.

Table F.3 provides good guidelines for implementing each of the hierarchy of risk control methods. It is very likely that more than one risk control method will be used for a given task.

- **Elimination** is the first priority (as it should always be), such as placing equipment into an electrically safe work condition.

- **Substitution** is often difficult to achieve unless it is a design element.

- **Engineering Controls** such as guarding are often used in conjunction with other methods. You can find more on guarding in the 70E & NETA column in the 2016 Summer issue of *NETA World Journal*.

Table 3: *NFPA 70E Table F.3*

Risk Control Method	Examples
(1) Elimination	Conductors and circuit parts in an electrically safe working condition
(2) Substitution	Reduce energy by replacing 120 V control circuitry with 24 Vac or Vdc control circuitry
(3) Engineering controls	Guard energized electrical conductors and circuit parts to reduce the likelihood of electrical contact or arcing faults
(4) Awareness	Signs alerting of the potential presence of hazards
(5) Administrative controls	Procedures and job planning tools
(6) PPE	Shock and arc flash PPE

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- **Awareness**, such as using signs, barrier tape, and *attendants*, is also often used with others.

- Hopefully, **Administrative Controls** would always be used to plan the task and guide technicians through it.

- Last is **PPE**, that is, appropriate PPE for the task and the hazard.

Used together, these risk control methods will greatly reduce the risk in performing electrical tasks, although even when using these methods, there will always be some residual risk or leftover risk that was not resolved. This residual risk must be evaluated to determine if it is still safe to perform the task.

Choosing rubber-insulated gloves and leather protector gloves is relatively simple. Figure 2 is an example of an ASTM glove chart reflecting Table 1 in ASTM F496, *Standard Specification for In-Service Care of Insulating Gloves and Sleeves*. The glove chart also shows the maximum-use voltage for each glove class, the label color it should have for that class, and the test voltages — both AC and DC. This example is from W.H. Salisbury, but many variations are available on the internet.

ARC FLASH BOUNDARY

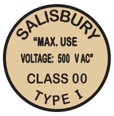
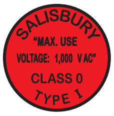
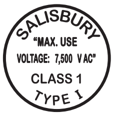
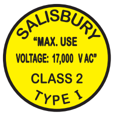
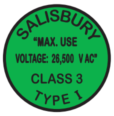
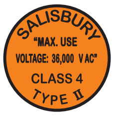
Shock boundaries are fairly straightforward. The arc flash boundary is more difficult. IEEE Std. 1584, *IEEE Guide for Performing Arc-Flash Hazard Calculations* was updated in 2018 with new calculations and parameters. The prior exception for systems less than 240 V/125 kVA has been eliminated, as recent testing has shown that sustainable arcs are possible, but less likely. Read that as "it could happen" and no one would like the results.

Arc flash kills three or four people a year. That may sound like a very small number (except to those who are killed), but the injuries from arc flash events are the cause of greatest concern. There are many injuries from arc flashes, and they carry life-changing consequences for those involved. As an expert consultant and expert witness, I have seen the damage these incidents can do. Regardless of who is at fault, the person who has been seriously injured by an arc flash will never be the same. Understanding how to determine the risk involved in a task, how to choose the appropriate PPE, and how to perform the task safely is paramount for technicians and is required to be considered a qualified person.

NFPA 70E statements about the arc flash risk assessment are almost verbatim from the shock risk assessment. Section130.5 states:

N *(A) General. An arc flash risk assessment shall be performed:*
(1) To identify arc flash hazards
(2) To estimate the likelihood of occurrence of injury or damage to health and the potential severity of injury or damage to health
(3) To determine if additional protective measures are required, including the use of PPE

N *(B) Estimate of Likelihood and Severity. The estimate of the likelihood of occurrence of injury or*

Class Color	Proof Test Voltage AC / DC	Max. Use Voltage AC / DC*	Blanket, Line Hose, Sleeve, Covers Label	Glove Label	Conventional Work Position for Electrical Worker or Lineman
00 Beige	2,500 V AC 10,000 V DC	500 V AC 750 V DC			Ground, Structure or Basket
0 Red	5,000 V AC 20,000 V DC	1,000 V AC 1,500 V DC			Ground, Structure or Basket
1 White	10,000 V AC 40,000 V DC	7,500 V AC 11,250 V DC			Structure or Basket
2 Yellow	20,000 V AC 50,000 V DC	17,000 V AC 25,500 V DC			Electrically Isolated Basket or Platform
3 Green	30,000 V AC 60,000 V DC	26,500 V AC 39,750 V DC			Electrically Isolated Basket or Platform
4 Orange	40,000 V AC 70,000 V DC	36,000 V AC 54,000 V DC			Electrically Isolated Basket or Platform

* Maximum use DC voltage is not part of any ASTM specification. Maximum DC voltages are valid in reference to IEC 903 only.

COURTESY W. H. SALISBURY

Figure 2: *ASTM Glove Labeling Chart*

damage to health and the potential severity of injury or damage to health shall take into consideration the following:
(1) The design of the electrical equipment, including its overcurrent protective device and its operating time
(2) The electrical equipment operating condition and condition of maintenance

***N** (C) Additional Protective Measures. If additional protective measures are required they shall be selected and implemented according to the hierarchy of risk control identified in 110.1(H). When the additional protective measures include the use of PPE, the following shall be determined:*
(1) Appropriate safety-related work practices
(2) The arc flash boundary
(3) The PPE to be used within the arc flash boundary

Table 130.5(C) shall be permitted to be used to estimate the likelihood of occurrence of an arc flash event to determine if additional protective measures are required.

Almost verbatim, Section 130.5(B), which contains some very important information, was added in addition to 130.5(A) and 130.5(C). The 70E user is to estimate the likelihood of occurrence and the severity of injury if an arc flash were to occur. Two items are listed to assist in determining the likelihood of occurrence:

1. The design of the equipment, the overcurrent protection, and the time of its operation
2. The operating condition of the equipment, including its condition of maintenance

Remember, if troubleshooting is being performed, the equipment is in distress. It is not in normal operating condition. Unmaintained electrical equipment is also hazardous, like a ticking time bomb that could go off at any minute. If any of these conditions indicate an issue, de-energize and isolate the equipment before continuing. No one has ever been promoted for injuring themselves or others or by damaging expensive equipment. Well, I do know one, but that was in the bad old days, and the facility manager thought the perpetrator was "a company man." Don't count on that today. Unsafe conduct is the quickest way out the door (or fence).

Section 130.5 states that Table 130.5(C) is permitted to be used to determine the likelihood of occurrence. "Permitted to be used" should read "use at your own risk." Careful evaluation is required to determine if Table 130.5(C) has any relevance at all. Table 4 shows a partial Table 130.5(C). For the most part, it does well on normally operating equipment. But what if there's a rat (or rats) in the circuit breaker? You would never see it coming. Of course, neither did the rats in this photo. No arc flash was initiated, but it was pretty close.

Table 4: *NFPA 70E Table 130.5(C)*

Task	Equipment Condition	Likelihood of Occurrence*
Reading a panel meter while operating a meter switch. Performing infrared thermography and other non-contact inspections outside the restricted approach boundary. This activity does not include opening of doors or covers. Working on control circuits with exposed energized electrical conductors and circuit parts, nominal 125 volts ac or dc, or below without any other exposed energized equipment over nominal 125 volts ac or dc, including opening of hinged covers to gain access. Examination of insulated cable with no manipulation of cable. For dc systems, insertion or removal of individual cells or multi-cell units of a battery system in an open rack. For dc systems, maintenance on a single cell of a battery system or multi-cell units in an open rack.	Any	No
For ac systems, work on energized electrical conductors and circuit parts, including voltage testing. For dc systems, working on energized electrical conductors and circuit parts of series-connected battery cells, including voltage testing. Removal or installation of CBs or switches Opening hinged door(s) or cover(s) or removal of bolted covers (to expose bare, energized electrical conductors and circuit parts). For dc systems, this includes bolted covers, such as battery terminal covers.	Any	Yes

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Once the likelihood of occurrence is determined, the potential severity of injury or damage to health must be appraised. This is where 130.5(B) comes into play. If an arc flash were to occur, what would be the impact on the person performing the work, others nearby, or the equipment? It could range from an "oops" to a disaster. Just as in the shock risk assessment, the arc flash risk assessment calls for additional protective measures, and once again, PPE is at the bottom of the options. I prefer to view IEEE 1584 calculations as educated estimates since everything has to work well for them to even be close. That is where normal operating condition and maintenance condition can make a huge difference. If the protective device does not operate within the manufacturer's specifications, there is no method to determine the resulting arc energy.

Calculations performed to the new edition of IEEE 1584 are best, but not always done. Table 130.7(C)(15) and Table 130.7(C)(16) are the backup plan. They are certainly not perfect, but as long as their limits are observed, they tend to be conservative. They are conservative because everything is "guesstimated." Better to be a bit over-protected than under-protected. If calculations have been made and arc flash warning labels are installed (and legible), Table 130.5(G) "is permitted" to be used to select PPE. For the sake of brevity, I'll skip using partials of those tables as figures.

CONCLUSION

The best plan is to avoid the hazard, reduce the risk, and wear PPE where appropriate. Back when the 70E first introduced the arc flash clothing selection tables (in the 2000 edition), Committee Chair Ray Jones said, "What people wear is not as important as that they wear something." This may sound all backwards today, but his point was that most technicians of the day weren't wearing any PPE for arc flash, so something was better than nothing. This was all pre-IEEE 1584, and there simply was no other guidance until Paul Hamer, then with Chevron, introduced the tables they used at their sites.

Electrical safety is an on-going project. Much like the National Electrical Code, it may never be finished, as much is learned every year. The 70E Committee members are unified in their goal to make the workplace safer. We don't always agree on how to meet that goal but, in the end, we come to a consensus we are satisfied meets the purpose. I once presented a paper, and a participant asked, "How can we trust the 70E if everyone doesn't agree?" My response: "Why wouldn't you want us to debate, arm wrestle, or whatever to provide the best safety standard possible?"

NFPA 70E is close to being in a maintenance phase where large revisions aren't necessary. The committee's focus has been to make 70E easier for the average technician to use and apply without having to ask for interpretations. It's there; it's clear and understandable. If you have any suggestions for the committee, a visit to the NFPA website (*nfpa.org/70e*) allows suggestions, comments, and public Inputs. ■

JAMES (JIM) R. WHITE, *Vice President of Training Services, has worked for Shermco Industries since 2001. He is a NFPA Certified Electrical Safety Compliance Professional and a NETA Level 4 Senior Technician. Jim is NETA's principal member on NFPA Technical Committee NFPA 70E®,* Electrical Safety in the Workplace*; NETA's principal representative on National Electrical Code® Code-Making Panel (CMP) 13; and represents NETA on ASTM International Technical Committee F18,* Electrical Protective Equipment for Workers. *Jim is Shermco Industries' principal member on NFPA Technical Committee for NFPA 70B,* Recommended Practice for Electrical Equipment Maintenance *and represents AWEA on the ANSI/ISEA Standard 203,* Secondary Single-Use Flame Resistant Protective Clothing for Use Over Primary Flame Resistant Protective Clothing. *An IEEE Senior Member, Jim was Chairman of the IEEE Electrical Safety Workshop in 2008 and is currently Vice Chair for the IEEE IAS/PCIC Safety Subcommittee.*

PROPER USE OF NON-CONTACT VOLTAGE PROBES AND SENSORS

BY TOM SANDRI, *Vector Power*

Tick tracer, glow meter, sniffer — they go by many names. Still, capacitive voltage sensors are all designed to do one thing: detect the presence of voltage in a wire or piece of equipment without direct contact with the conductor or energized part. These test tools are popular because they're inexpensive, easy to use, and small enough to fit in a shirt pocket.

LOW-VOLTAGE CAPACITIVE VOLTAGE SENSOR

Capacitive voltage sensors are convenient and can quickly help you identify energized conductors without exposing the energized conductor. Note that most (if not all) of these devices are only suitable for AC; they will not detect DC voltages. Per NFPA 70E, you must test phase-to-phase and phase-to-ground when determining if a circuit is de-energized. When working on circuits operating at less than 1,000 volts, the accepted method for testing the absence of voltage is to use a voltmeter to perform phase-to-phase and phase-to-ground voltage checks. For circuits with voltages greater than 1,000 volts, NFPA 70E permits using a non-contact voltage probe, as the stronger electrostatic fields in these situations make detection more reliable.

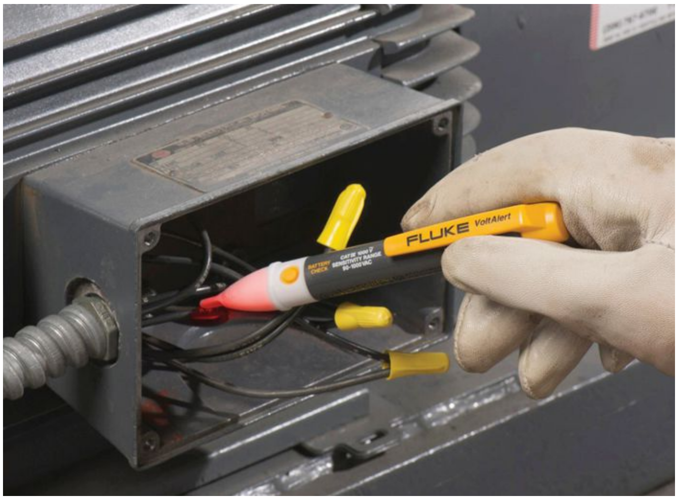


Figure 1: *Non-Contact Voltage Probe*

What Is the Operation Principle behind this Test Instrument?

The test instrument works on the principle of capacitive coupling (Figure 2). To understand this, let's review electrical circuit theory and recall how a capacitor works. A capacitor has two conductors, or plates, separated by a non-conductor called a dielectric. If we connect an AC voltage across the two conductors, AC will flow as the electrons are alternately attracted or repelled by the voltage on the opposite plate.

In other words, there's a complete AC circuit even though there's no hard-wired circuit connection. The electrical field inside the capacitor between the two plates is what completes the AC circuit.

Capacitors are often considered individual circuit components, but the world is full of small stray capacitors you might not usually consider. For instance, suppose you're standing on a carpeted concrete floor directly under a 120 V light fixture, and the light is on. Your body is conducting a tiny AC current because it's part of a circuit with two series capacitors. One capacitor's two conductors or plates are the live elements in the light bulb and your body. The dielectric is the air between them. The two conductors for the second capacitor are your body and the concrete floor. The dielectric for the second capacitor is the carpet, plus your shoes and socks.

This second capacitance is much larger than the first. Understanding how the voltage divides between these two capacitors in series is critical to understanding how the capacitive voltage sensor works.

Let's return to the electrical circuit theory again. In a series circuit, the most significant voltage will develop across the largest impedance (Ohm's Law). With capacitors, the smaller the capacitance, the larger the impedance, known as capacitive reactance. Thus, the most significant voltage will develop across the smallest capacitor when two capacitors are in series.

In this example, only a few volts will develop between your feet and the floor (the large capacitor), while the remainder of the 120 V will be between your head and the light bulb (the small capacitor).

Suppose you hold the barrel of a capacitive voltage sensor in your hand and place it near the light fixture's conductors. In that case, you're inserting a high-impedance-sensing element into a capacitively coupled series circuit. Your hand, arm, body, and feet form a relatively large capacitor coupled to the floor. The sensor tip is a small capacitor coupled to the live conductor. As a result, the sensing circuit in the tester detects voltage and signals to you via a lamp, tone, ticking noise, or buzzer that voltage is present. Thus, the nicknames are glow meter, tick tracer, and sniffer.

Figure 2: *Stray Capacitance*

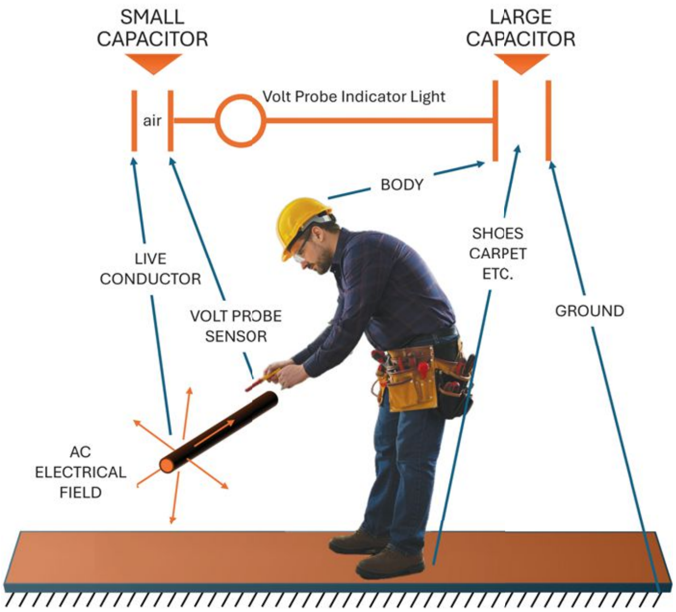


Figure 3: *Voltage Probe Theory*

Will the Sensor Work as Designed if You Are Not Holding It or Are on a Wooden Ladder?

The simple answer is no. This is because you've opened the capacitively coupled circuit by removing your hand from the sensor or sufficiently isolated yourself from the ground. As noted above, capacitively coupled circuits must be closed (complete) for current to flow. Whenever the dielectric between two conductors is increased so much that the field between the two conductors is diminished to the point of ineffectiveness, the circuit opens.

Another way to conceive of this is to think of the effective capacitance at that point in the circuit as becoming smaller and smaller because of the increase in dielectric. Capacitive reactance (X_c) increases as capacitance decreases and continues to grow to the point where virtually all the voltage drop occurs across this now-open circuit element. Any remaining voltage drop in the capacitive sensor portion of the circuit is now too small to activate the test instrument.

The capacitive sensor must have a sufficient ground connection — typically via the operator — for the tester to operate as intended.

Will the Tester Work on a Shielded Cable or through a Metal Enclosure?

No. The tester won't work if the capacitive sensing path is interrupted by a metal shield, such as a metallic conduit or a metal enclosure (assuming that both are effectively grounded). It can't detect voltage inside a metal enclosure, grounded metal conduit, or shielded cable. On the other hand, if the sensor does activate on a metal conduit or a metal enclosure, this indicates that those surfaces are not effectively grounded and pose a shock hazard.

Now that we understand exactly how the low-voltage capacitive sensor works, we can better understand why NFPA 70E does not recommend using this technique as a primary voltage detection method on circuits operating at voltages lower than 1,000 volts.

NON-CONTACT MEDIUM VOLTAGE TEST PROBES

NFPA 70E, *Standard for Electrical Safety in the Workplace*, provides an exception for testing for the absence of voltage on circuits above 1,000 volts alternating current. For circuits above 1,000 volts, you are required to test phase-to-ground voltages. Plus, we are dealing with higher voltages to overcome the voltage drop sensitivity. Therefore, most of the test probes on the market are non-contact test probes that measure voltage from phase to ground. There are phasing sticks and other means to measure phase-to-phase, but typically, non-contact test probes are used for testing for the absence of voltage.

Non-contact AC voltage detectors verify live or de-energized conductors. Since voltage and the electrostatic field that is being detected have a causal relationship, the fields above 1,000 volts are stronger, and the detectors can be used with hot sticks and the splined universal end fitting. Testers indicate the presence of voltage with an extra-bright LED light and a distinctive audible signal. Non-contact AC voltage detectors alarm in the proximity of electric fields.

Figure 4: *Medium-Voltage Non-Contact Probe*

As the name suggests, non-contact voltage detectors can be used without touching the electrical supply and flash or beep when near a power source. Voltage detectors actually detect electric fields rather than voltage itself. Electric fields are created by voltage, and the two have a causal relationship, which means that the higher the voltage, the greater the electric field.

Magnetic fields are created by the current and have the same causal relationship as the electric fields and voltage. Electromagnetic waves are emitted from sources with a voltage, which is what the non-contact voltage detector senses. The internal circuit of a non-contact voltage detector leads to an antenna or sensor positioned at the tip or end of the voltage detector. When the electromagnetic waves hit the antenna, a signal is sent through the circuit, which turns on the light and/or buzzer.

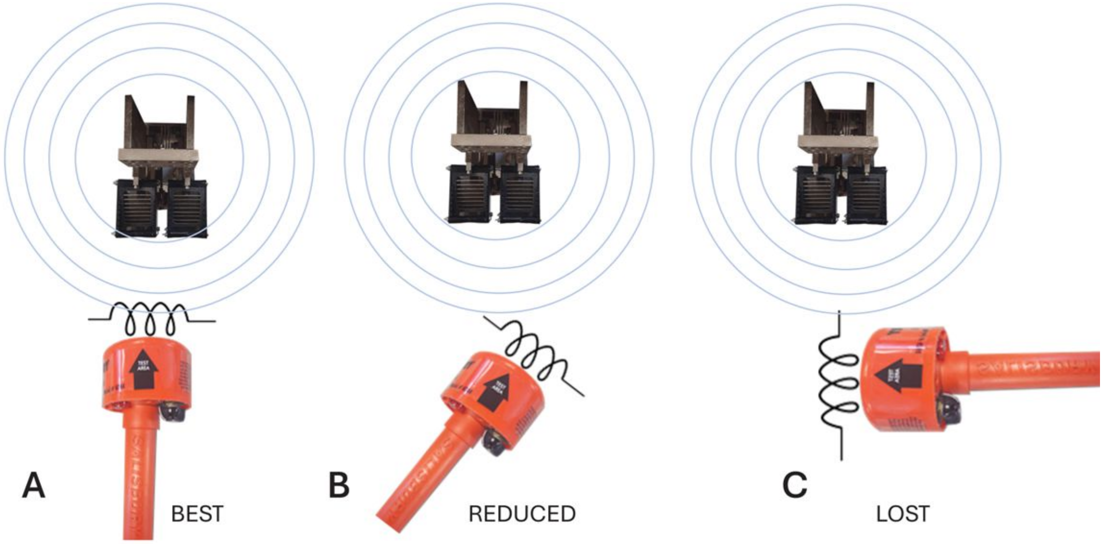


Figure 5: *Antenna Angle and Electric Field*

Antenna Angle and Electric Field

Maximum sensitivity is accomplished when the probe is parallel with the target. At this alignment, the maximum electric field is passing through the antenna. Sensitivity is reduced or lost when the antenna is not parallel with the target.

Probing along a Stress Cone

As stated earlier, a non-contact AC voltage detector detects electric fields. The greater the voltage, the greater the electric field, and thus, the better the measurement sensitivity. When probing along a stress cone, remember that the stress cone reduces the percentage of line voltage as you move across it. Therefore, the electric field at the bottom of the stress cone is at its lowest percentage of line voltage and has the smallest electric field. As you move up the stress cone to the cable end, the line voltage increases as seen in Figure 6, and the fields become stronger.

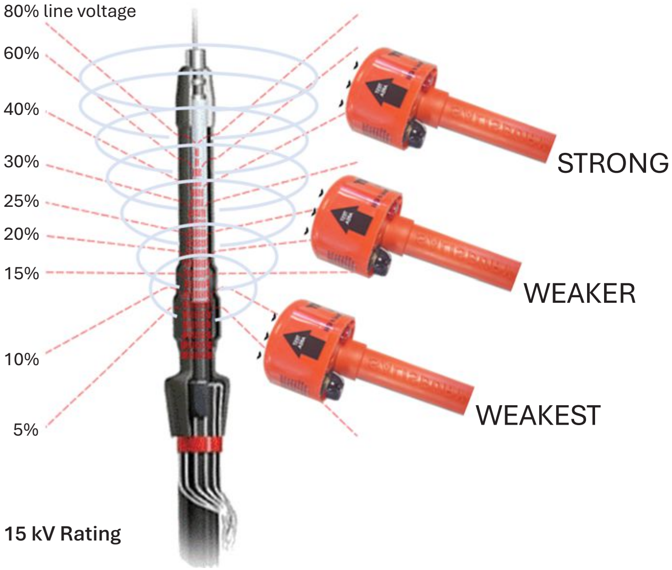


Figure 6: *Probing along a Stress Cone*

Probing Along a Dead-Break or Load-Break

A dead-break elbow (Figure 7) requires the cable to be dead to be detached or attached and is typically rated for 600 A. A load break elbow can be attached or detached live or under load and is generally rated for 200 A. The primary difference between these terminations is the ability to detach the connector, live or dead. One significant similarity between the dead and load breaks is the semi-conducting outer envelope. This outer envelope (or jacket) is made

Figure 7: *Probing along a Dead-Break or Load-Break*

of semi-conducting EPDM. Its design relieves electrical stress, as does a cable screen/shield.

Its connection to the cable screen ensures the assembly is maintained at Earth's potential. Since this semi-conducting outer envelope acts as a screen, the absence of voltage detection is impossible. Since the outer envelope/jacket on a dead break and load break are semi-conductive and maintain the assembly at earth or ground potential, the test point is another similarity in these terminations. The test point is electrically protected by a cap made of semi-conducting EPDM. The test point is a capacitive voltage divider that enables the assembly to be checked for the absence of voltage before removing the connector. Note: The semi-conducting cap must be removed with a high-voltage stick before making the absence of voltage measurement. The cap is semi-conductive and will act as a shield.

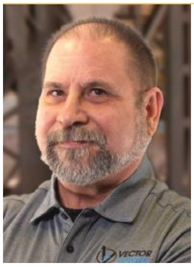
It should also be noted that not just any non-contact A-C probe will work on these accessories. The voltage test point is a capacitively coupled connection, not directly connected to the conductor. Not all non-contact voltage probes are designed for this task. To determine if the cable is energized, you must test it with a suitable sensing device intended for use with detachable connections manufactured with capacitive test points. Do not use conventional voltage measuring equipment. Test with an appropriate sensing device that works on a capacitively coupled test point. For example, the underground residential distribution or URD mode found on specific Salisbury Voltage Detector models has been designed to work with these connectors.

REMEMBER

Performing an absence of voltage test on all electrical components and circuits is critical to the safety of electrical workers. Never attempt to touch an electrical component or circuit until you have proven it to be de-energized!

Low-voltage capacitively coupled sensors can be a convenient tool, but without a firm understanding of how they work, they can be dangerous and provide a false reading. Whenever the dielectric between two conductors increases so much that the field between the two conductors diminishes to the point of ineffectiveness, the circuit opens, and the low-voltage capacitive sensor is rendered ineffective.

NFPA 70E, *Standard for Electrical Safety in the Workplace,* and CSA Z-462, *Field Electrical Safety Standards*, do not allow a non-contact sensor to be used as a primary tool for the absence of voltage readings on any circuit 1,000 volts or less. Readings must be performed with a voltmeter, phase-to-phase, and phase-to-ground. NFPA 70E provides an exception for testing for the absence of voltage on circuits above 1,000 volts alternating current. ■



THOMAS SANDRI *is Director of Workforce Development at Vector Power, where his responsibilities include the design and development of learning courses. He has been active in the field of electrical power and telecommunications for over 35 years. During his career, Sandri has developed numerous training aids and training courses, has been published in various industry guides, and has conducted seminars domestically and internationally. Sandri supports a wide range of electrical and telecommunication maintenance application disciplines. He has been directly involved with and supported test and measurement applications for over 25 years and is considered an authority in application disciplines including insulation system analysis, medium- and high-voltage cable, and partial discharge analysis, as well as battery and DC systems testing and maintenance. Sandri earned a BSEE from Thomas Edison University in Trenton, New Jersey. He received NETA's Alliance Recognition Award in 2024.*

SHOCKED?

BY TERRY BECKER, *TW Becker Electrical Safety Consulting, Inc.*

All workers on a worksite are at risk of receiving an electric shock that could be fatal. Only specific qualified persons should be exposed to an abnormal arcing fault and arc flash. In the United States, OSHA electrical incident reports provide lagging statistics validating that a fatality due to electrocution occurs at least every 1 to 2 days.[6] In Canada, an electrocution may occur several times a month.

Workers often don't report minor electric shock incidents, and the injuries are frequently invisible. If statistics included these unreported incidents, thousands, if not tens of thousands, possibly hundreds of thousands of electric shocks likely occur in North America every day. Globally, electric shock and electrocution events are in the millions per day, with hundreds of thousands of fatalities likely. We need more focus on the electric shock hazard!

As a qualified person, how many times have you received an electric shock at work: Never? 1 to 10 times? 11 to 50 times? 51 to 100 times? Or more than 100 times? I am sure we would not be surprised at the broad spectrum of answers to this question depending on the age range and experience in the room.

From 1942 to 1960, the *American Electrician's Handbook*[4] taught workers to use their hands to check for the absence of voltage up to 250 V AC. For low-voltage DC bell/signal wiring, simply "taste" electricity by placing the wires across your tongue. Believe it or not, it is true — I have the 1953 Edition hardcopy.

SHOCK SEQUELAE

Until recently there was limited awareness that, besides the immediate effects of electric shock (Table 1), there are potentially long-term sequelae from receiving electric shocks.[2]

Table 1: *Effects of Electrical Current Flow through the Human Body*[3]

Current mA (milli-amps, 60 Hz)	Physiological Effect on Human Body	Human Perception and Effect on Human Body
< 1ma	None	Imperceptible
1 mA	Perception threshold	Mild sensation
1-10 mA		Painful sensation
10 mA	Paralysis threshold of arms and hands	Cannot release hand grip, "no let-go" threshold
30 mA	Respiratory paralysis	Breathing may stop
75 mA	Heart fibrillation possible	Heart action uncoordinated
250 mA	Heart fibrillation	99.5%, ≥5 second exposure
4 amps	Heart paralysis threshold	Heart stops for the duration of current flow
5 amps or greater	Tissue burns	Most likely fatal. Vital organs are burned or damaged. Can lead to limb amputation.

Note: The amount of current, the current flow path through the human body, frequency, and length of time of current flow through the human body determines heart fibrillation probability. Male and female body resistance will be different and added muscle mass increases conductivity. Wet or dry skin at the point of current entry will impact current flow.

Table 2: *Human Error Precursor Identification*[1, 2]

Item #	Human Error Precursor Group & Description
	Task Demands
1	Time pressure, in a hurry
2	High workload, memory requirements
3	Simultaneous or multiple work tasks
4	Repetitive actions or monotony
5	Critical steps or irreversible acts
6	Interpretation requirements
7	Unclear goals, roles, or responsibilities
8	Lacking or unclear standards
	Work Environment
9	Distractions, interruptions
10	Changes, departures from routine
11	Confusing displays or controls
12	Workarounds, out-of-service instrumentation
13	Obscure electrical supplies or configurations
14	Unexpected equipment conditions
15	Lack of alternative indications
16	Personality conflicts
	Individual Contributions
17	Unfamiliar with or first-time performing task
18	Lack of knowledge (faulty mental model)
19	New technique not used before
20	Imprecise communication habits
21	Lack of proficiency or experience
22	Indistinct problem-solving skills
23	Unsafe attitudes for a critical task
24	Inappropriate values
	Human Nature
25	Stress (limits attention)
26	Habit patterns
27	Assumptions
28	Complacency or overconfidence
29	Mindset
30	Inaccurate risk perception
31	Mental shortcuts (biases) or limited short-term memory

EXTENSION CORDS

Non-electrical workers are potentially at a greater risk of receiving an electric shock using portable cord-and-plug-connected electrical equipment and extension cords. This is further exacerbated by the fact that non-electrical workers have been conditioned or taught that they can use electrician's tape to repair damaged cords and cord plug ends. Recently, while training non-electrical workers at a large mine site using damaged extension cords as training props, an attendee took electrician's tape out of his pocket and taped up a damaged extension cord. Workers who plug an extension cord into a GFCI must self-test and reset the GFCI to confirm the proper function of the GFCI, but most workers do not.

Extension cords are found in permanent use when they are intended for temporary power only and are prone to a higher risk of damage. Extension cords should be removed from service after use, unplugged at the receptacle, rolled up, and stored to protect them from damage when not in use. Proper extension cord usage and cord management training are required. Specifying an extension cord for the service (e.g., extra hard usage, appropriate wire gauge, and outdoor cold temperature-rated) can reduce the likelihood of damage.

WHY DO ELECTRIC SHOCKS OCCUR?

I define effective human performance as:

"…a worker's ability to manage factors that may interfere with the effectiveness of risk controls."

As outlined above, workers were taught to accept electric shock as part of the job or use their bodies as voltage detectors. Workers were taught they could use electrician's tape to repair damaged cords. Extension cords were not specified for the intended use. Do qualified persons receive more electric shocks than non-electrical workers? Are there underlying human performance issues and human error pre-cursors that could provide some insight?

In NFPA 70E Annex Q, Table Q.5 or CSA Z462 Annex U Human Performance and Workplace Electrical Safety, Table Q.5 or Table U.1 Error Precursor Identification and Human Performance Tool Selection provides a detailed list of potential error precursors (Table 2). Some of the error precursors listed are the reasons workers receive electric shocks in the workplace.

WHAT CAN WE DO TO MANAGE HUMAN ERROR PRE-CURSORS?

A formal risk assessment procedure included in a compliant electrical safety program, completed by the employer and validated at least annually, is the best method to ensure sustainable and measurable results. Selection and application of many of the hierarchy or risk control methods illustrated in Figure 1 can positively impact human error pre-cursors and reduce the likelihood of occurrence or exposure to electric shock.

As a priority, the key prescriptive requirements of NFPA 70E or CSA Z462 collectively can be used by an employer to manage human error precursors for Qualified Persons and non-electrical workers. The potential hierarchy of risk control methods selected may also vary from employer to employer. Specific options include:

- Establish an electrically safe work condition using lock out/tag out (LOTO).
- Use defined roles and responsibilities in an electrical safety program.
- Audit your electrical safety program.
- Use guarded, finger-safe, and fully insulated conductors and circuit parts.
- Install rubber insulating blankets.
- Provide electrical safety training for all workers.
- Use electrical safety bulletins for more frequent messaging.
- Complete a risk assessment procedure.
- Complete and document an electric shock risk assessment.
- Conduct a field-level hazard assessment (FLHA).
- Qualified person fills out an energized electrical job safety planning form before completing energized work.
- Develop switching and isolation procedures.
- Ensure qualified persons check for any back-feeds.
- Use a pre-energization checklist.
- Emphasize human error precursors in monthly safety meetings.
- Establish electrical safe work procedures.
- Control extension cords specified for a workplace (e.g., extra hard usage, -60°C rated, etc.).
- Use extension cord protectors in high-traffic welding, truck, metalworking, and carpentry shops.
- Develop an extension cord management procedure.
- Formalize pre-use inspection of cords before use.
- Ensure GFCI test and reset before plugging in an extension cord.
- Employer implements an assured equipment grounding conductor program.
- Schedule tailboard/tailgate meeting.
- Self-check with verbalization.
- Use three-way communication.
- STOP when unsure.
- **Test-Before-Touch!**

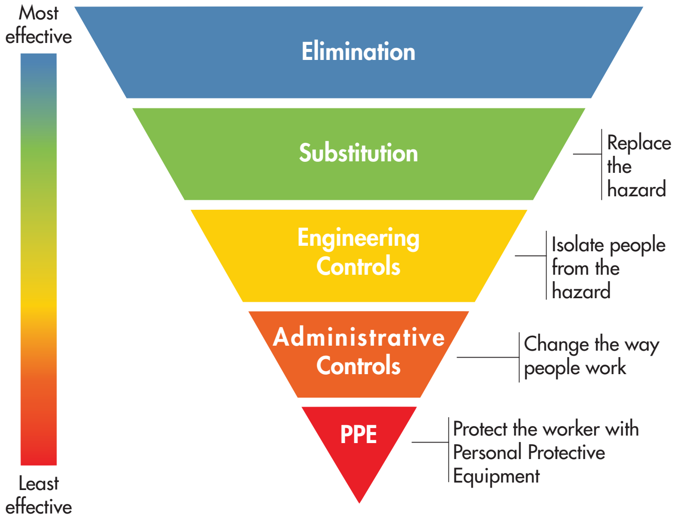


Figure 1: *Hierarchy of Risk Control Methods*

HOW CAN WE MANAGE THE FREQUENCY OF ELECTRIC SHOCKS AND ELECTROCUTIONS?

Statistically, electric shock hazards have not been managed effectively since the invention of electricity. Electric shocks and electrocutions are still occurring at a high frequency in North America. Per OSHA reports on severe injury and incident statistics, there were only 433 arc flash burn injuries out of 82,333 severe injuries in a seven year, four month period. A disproportionate focus has been placed on arc flash that has overwhelmed the safety narrative in the industry when compared to electric shock.[4] OSHA's reports on severe injury incident statistics provide detailed information that supports this statement.

More focus on electric shock is required for all workers, but specifically non-electrical workers using portable cord-and-plug-connected electrical equipment and extension cords. A GFCI self-test and reset are required before plugging in an extension cord. This must be emphasized in training and safety communication and audited.

Qualified persons need to use appropriate voltage-rated PPE, tools, and equipment. Ensure rubber insulating gloves have been dielectrically tested at least every six months, stored properly, pre-use inspected, and worn when hands must go inside the restricted shock protection boundary, especially for low-voltage electrical equipment. ■

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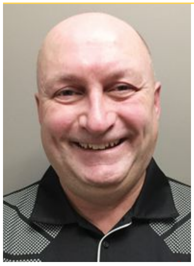


TERRY BECKER, P.ENG., CESCP, IEEE SENIOR MEMBER *an Electrical Safety Specialist and Management Consultant. He is the first past Vice-Chair of the CSA Z462, Workplace Electrical Safety Standard Technical Committee, and a Voting Member and Working Group Leader for Clause 4.1 and the Annexes. Becker is a founding member and Voting Member on the CSA Z463, Maintenance of Electrical Systems Standard, and a Voting Member of the IEEE 1584, Guide for Performing Arc-Flash Hazard Calculations. He has presented at conferences and workshops on electrical safety in Canada, the USA, India, Italy, and Australia. Becker is a Professional Engineer in the Provinces of BC, AB, and ON.*

ADDRESSING THE RISKS OF **LITHIUM BATTERY SYSTEMS**

BY TYSON BITTRICH, *Mayfield Renewables*

Lithium battery safety is a hot topic for installers, authorities having jurisdiction (AHJs), and local communities. The perceived safety of lithium-ion battery (LIB) systems often focuses on fire risk even though the present benchmark testing method, UL 9540A, *Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems Standard,* is keen to place fire risk alongside the risks of off-gas and explosion.

This article delves into the off-gas and explosion risks of LIBs to:

1. Understand why these risks warrant increased attention.
2. Identify key stakeholders most directly impacted.
3. Anticipate the development of new testing methods and standards that will help better address these challenges.

THE CONTEXT OF UL 9540A

Whereas UL 9540, *Energy Storage System (ESS) Requirements,* is the safety standard to which LIB will be listed, UL 9540A is the corresponding test method that lays out, in sequential detail, how a recognized test laboratory is to conduct the test. Underwriters Laboratory released its current 4th Edition, *Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems Standard,* in 2019. Since then, this test method has become especially relevant for LIB systems intended for installation with tighter than 3 feet spacing between and around battery groups. UL 9540A-interpreted reports can support a given AHJ's decision to allow (or disallow) this narrower spacing. The same goes for energy capacities exceeding the stated maximum allowable quantities for battery groups. See NFPA 855–2023: 9.4.2 and IFC 1207–2024:5.1 and 5.2 for specifics.

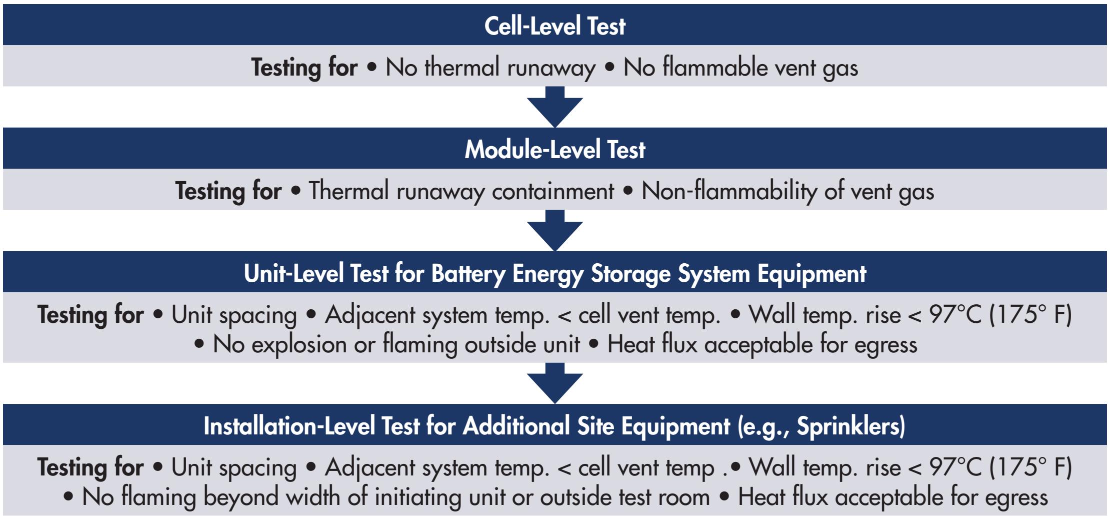
Thermal Runaway

The goal of UL 9540A is to observe and quantify the initiation and propagation, not of a flaming fire or an explosion, but of thermal runaway. Thermal runaway (TR) can be defined as the:

…"*self-heating of an electrochemical system in an uncontrollable fashion… [that] progresses when the [battery] cell's heat generation is at a higher rate than it can dissipate, potentially leading to off-gassing, fire, or explosion"* (NEC 2023, 2020)

The most precise data is collected at the cell level. Starting with the smallest functional component of the LIB product under test, testing technicians seek out timing, temperature, and thermal ramp-up rate at which TR begins. The logic of the test mirrors the progressive four levels of the test method itself (Figure 1).

After the cell level test, the story is not only about initiating TR in one cell but also about assessing the possibility of TR propagation to a neighboring cell, module, or unit. The more data derived at the cell



Cell-Level Test

Testing for • No thermal runaway • No flammable vent gas

Module-Level Test

Testing for • Thermal runaway containment • Non-flammability of vent gas

Unit-Level Test for Battery Energy Storage System Equipment

Testing for • Unit spacing • Adjacent system temp. < cell vent temp. • Wall temp. rise < 97°C (175° F) • No explosion or flaming outside unit • Heat flux acceptable for egress

Installation-Level Test for Additional Site Equipment (e.g., Sprinklers)

Testing for • Unit spacing • Adjacent system temp. < cell vent temp .• Wall temp. rise < 97°C (175° F) • No flaming beyond width of initiating unit or outside test room • Heat flux acceptable for egress

Figure 1: *UL 9540A Flow Chart* MAYFIELD RENEWABLES, INC. © 2025

level we can repeatably verify at the module, unit, or installation levels, the better we can characterize, assess, and manage that LIB product's TR risk. For further details on this method, consult your trusted educational partners, as this test includes much more nuance and complexity.

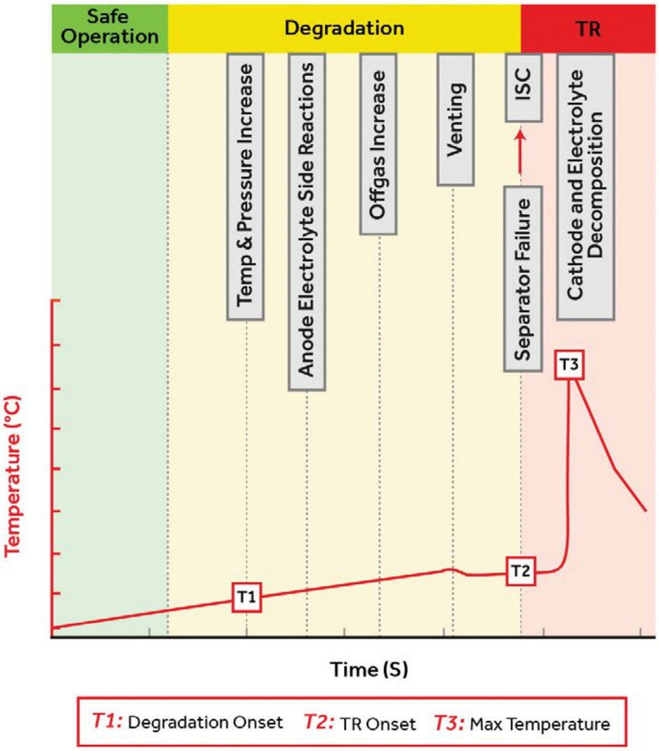


Figure 2: *Thermal Runaway Chart*
MAYFIELD RENEWABLES, INC. © 2025

LIBs have a safe operating temperature range. In healthy lithium-ion battery operation, LIB behavior is reversible (charge and discharge), repeatable, and occurs at a predictable voltage. Erring outside intended temperature and voltage conditions carries risk. We can visualize the progression of a LIB cell from safe operation to degradation to uncontrollable TR by plotting cell temperature over time (Figure 2). As a LIB cell experiences temperature increases, the effects of undissipated heat can be seen in several degradation events.

The point of no return — the onset of TR — coincides with electrode separator failure and an internal short circuit. To date, all observed cases of thermal runaway involve an internal short circuit. Hereafter, rapid thermal increase is inevitable and quick.

One common misconception is that if we could simply avoid the onset of TR, LIBs would be fire- and explosion-risk-free. To base battery safety design and installation solely on avoiding TR is an incomplete strategy. Notice the temperature curve near venting just before this onset moment. Off-gassing begins in this venting moment before TR starts and continues through TR onset. What are the constituents of this off-gas? What are the concentrations? How much flammable off-gas is too much at venting?

Gas Composition

UL 9540A answers similar questions and establishes a quantifiable threshold for unsafe levels of flammable off-gassing at the cell level. In accordance with Section 7.4 of the 4th edition, TR is initiated in the cell within a pressurized vessel (Figure 3) to collect component gases at venting with the best possible precision. After gas composition and mixture are determined using gas chromatography and infrared spectroscopy, this mix of flammable gases is synthesized to enable further characterization.

From this synthetic reproduction of the gas mixture, a lower flammability limit (LFL) for the gas mixture can be determined. Often reported as a percentage of air volume, LFL indicates the concentration at which a given volume of air containing the flammable gas mix could be ignited.

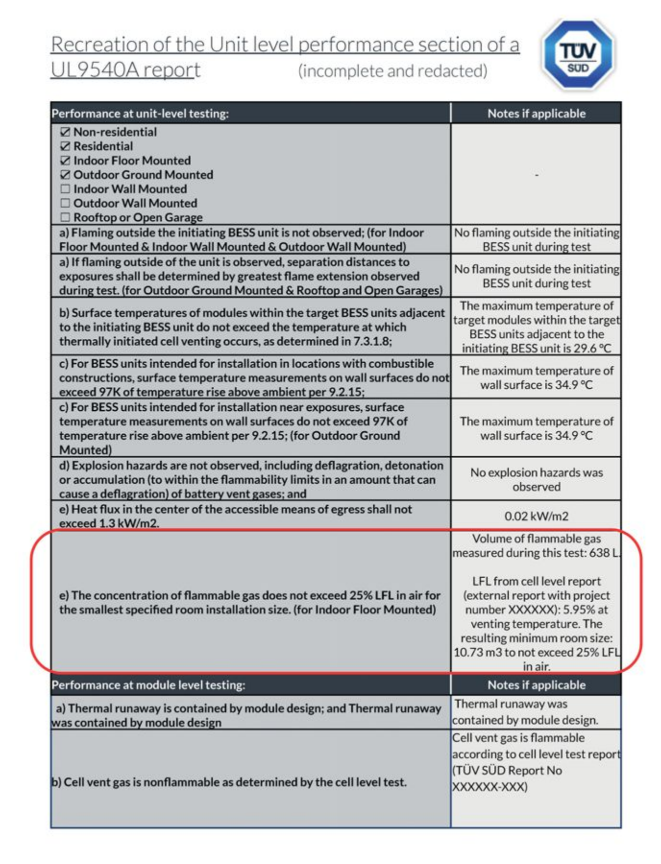
Having established baseline characterization of TR in pressurized environs at the cell level, the three subsequent levels are performed under the safety of a hood and exhaust system. The module-level test is a verification step of the cell level. Can we repeat the observation of the overall gas mix volume released in venting, with the same or similar mixture ratios? Are the temperature and rates corresponding to venting at this test level similar enough to the exhibited temperatures and rates at the previous test level?

At the unit level, a given gas mixture's LFL recorded at the cell level and verified at the module level will help establish a key performance criterion. The unit level assesses gas explosion risk by setting a conservative threshold: one-quarter of the LFL by total volume. Figure 4 shows an example 9540A report from TUV that reads:

The concentration of flammable gas does not exceed 25% LFL in air the smallest specified room installation size.

In theory, a venting LIB that has not yet reached thermal runaway or is not subjected to active flame would only pose off-gas risk at LFL concentrations. In practice, a brief study of the short history of LIB fires in the USA reveals that vented gases at various unknown concentrations have become the fuel source leading to ignition and explosion. TR alone may not be a primary or sufficient cause for many large battery energy storage system (BESS) fires. The public data shows that many BESS fires have stemmed from external causes or broader system

Figure 3: *Pressure Vessel*
PHOTO COURTESY OF MOTISTECH



Recreation of the Unit level performance section of a UL9540A report (incomplete and redacted)

Performance at unit-level testing:	Notes if applicable
☑ Non-residential ☑ Residential ☑ Indoor Floor Mounted ☑ Outdoor Ground Mounted ☐ Indoor Wall Mounted ☐ Outdoor Wall Mounted ☐ Rooftop or Open Garage	-
a) Flaming outside the initiating BESS unit is not observed; (for Indoor Floor Mounted & Indoor Wall Mounted & Outdoor Wall Mounted)	No flaming outside the initiating BESS unit during test
a) If flaming outside of the unit is observed, separation distances to exposures shall be determined by greatest flame extension observed during test. (for Outdoor Ground Mounted & Rooftop and Open Garages)	No flaming outside the initiating BESS unit during test
b) Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit do not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8;	The maximum temperature of target modules within the target BESS units adjacent to the initiating BESS unit is 29.6 °C
c) For BESS units intended for installation in locations with combustible constructions, surface temperature measurements on wall surfaces do not exceed 97K of temperature rise above ambient per 9.2.15;	The maximum temperature of wall surface is 34.9 °C
c) For BESS units intended for installation near exposures, surface temperature measurements on wall surfaces do not exceed 97K of temperature rise above ambient per 9.2.15; (for Outdoor Ground Mounted)	The maximum temperature of wall surface is 34.9 °C
d) Explosion hazards are not observed, including deflagration, detonation or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases; and	No explosion hazards was observed
e) Heat flux in the center of the accessible means of egress shall not exceed 1.3 kW/m2.	0.02 kW/m2
e) The concentration of flammable gas does not exceed 25% LFL in air for the smallest specified room installation size. (for Indoor Floor Mounted)	Volume of flammable gas measured during this test: 638 L. LFL from cell level report (external report with project number XXXXXX): 5.95% at venting temperature. The resulting minimum room size: 10.73 m3 to not exceed 25% LFL in air.
Performance at module level testing:	**Notes if applicable**
a) Thermal runaway is contained by module design; and Thermal runaway was contained by module design	Thermal runaway was contained by module design.
b) Cell vent gas is nonflammable as determined by the cell level test.	Cell vent gas is flammable according to cell level test report (TÜV SÜD Report No XXXXXX-XXX)

Figure 4: *UL 9540A Mockup Report*

Figure 5: *UL 9540A Key Stakeholders*
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design issues — such as external shorts, faulty cabinet installation, or water ingress — rather than from thermal runaway propagation alone.

Moreover, all lithium-ion chemistries to date can be driven into thermal runaway at the cell and module levels of the test and carry inherent flammable off-gassing risk. This includes the popular lithium iron phosphate (LiFePO4) batteries, which offer a higher onset temperature compared to its higher energy-density nickel-manganese cobalt cousin. While this means more stable operation and delays the onset of TR onset, that fact doesn't preclude LFP batteries from being the fuel source in explosion and fire due to failures like water ingress, external shorts, and other contingencies beyond the battery of the BESS.

For more on LFP thermal runaway history, see SEAC's Informational Bulletin on the UL 9540 Safety Standard and the UL 9540A Test Method, which provides a high-level overview of ANSI/CAN/UL 9540, *Energy Storage Systems and Equipment* and the UL thermal runaway fire propagation test method in ANSI/CAN/UL 9540A, *Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems (BESS).*

MITIGATING RISK

Outside the test labs at large commercial or industrial installation sites, not all off-gassing is routinely detected. Not all systems installed comply with the latest version of NFPA 68, *Standard on Explosion Protection by Deflagration Venting,* and/or NFPA 69, *Standard on Explosion Prevention Systems.* More data and greater clarity are required. Proper battery system design, accurate gas detection systems, and proper installation of the non-battery components of the total system are required to mitigate risk.

This is not to say that lithium-ion batteries are prohibitively dangerous. Most energy technologies pose inherent safety risks during early adoption. Few categories are as young and quickly evolving as LIB. With LIB BESS, we are bringing projects closer to homes, humans, and other exposures than with 20th-century energy generation resource types. As we work to deploy more energy storage to modernize the grid, augment and support distributed energy resources, and accelerate a needed energy transition, accurate and candid communication — even around potentially worrisome topics like fire and explosion risk management — will serve us better.

PROTECT THOSE WHO PROTECT US UNDER DURESS

More energy storage is vital to the energy transition ahead of us, but we must also do so as safely as possible for all stakeholders — and there are many (Figure 5).

Fire service professionals are the most directly affected by potentially dangerous scenarios at a BESS site. From their perspective, the risk of explosion is often a significantly greater concern than fire. In training, the fire service traditionally trains for two LIB states only: normally operational and actively on fire. Any state in between represents too considerable a risk of an explosion to use typical rules and protocols of engagement. As one subject matter expert offered:

From a first responder perspective, we need to know what a safe level and distance of engagement is to even put a serviceperson into an incident command post. We'd rather have a known ongoing battery fire than

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an unmonitored off-gassing event ripe for explosion. Once the unit or system is on fire, at least we know an explosion is much less likely, which sounds like a strange win.

Prioritizing the safety of our fire service professionals by sacrificing the BESS and all related assets, some LIB manufacturers have even engineered solutions that intentionally light off-gasses once the "25% of LFL" threshold is detected rather than risk an escalating explosion hazard potentiality.

THE LARGE-SCALE FIRE TEST

Currently, UL 9540A does not spell out how to intentionally ignite off-gas at any stage in the test because it does not require intentional ignition. As its name implies, the *Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems Standard* is explicitly written to characterize thermal runaway initiation and propagation. It is not intended to be used to collect data on fire initiation and fire propagation.

Industry stakeholders are keen to address this gap. A few manufacturers have spent time and resources to perform their proprietary unit fire tests with ignition. Others aim to publicize their catastrophic large-scale fire results and methods.

The code-making panels, too, are looking ahead to a shared set of methods in the next round of codes and standards governing. While not finalized, changes to key the chapter of NFPA 855, *Standard for the Installation of Stationary Energy Storage Systems,* have received two rounds of comment and criticism. Note: Public access to the draft language is free and accessible with a trial membership to *NFPA.org*). If the current draft becomes final and is adopted by your jurisdiction, Chapter 9 of NFPA 855 will explicitly call for a large-scale fire test as a separate test from UL 9540A. Combined, these two tests will:

- Intentionally ignite vent gases to assess the fire propagation hazard
- Show that a fire involving one ESS unit will not propagate to an adjacent unit

The call for large-scale fire testing alone won't remedy the current gap. We need consensus on a standardized large-scale fire test. This need brings us to another stakeholder set: the nationally recognized test laboratories, or NRTLs.

One such NRTL, the CSA Group, published a promising large-scale fire test procedure in late 2024. Their TS-800 spells out methods to conduct a large-scale fire test with intentional ignition of off-gases to characterize and quantify active fire propagation risk from one populated unit to another. Just as the UL9540 standard requires the UL 9540A test method, the CSA Group intends their forthcoming ANSI standard, CSA C800, will incorporate the TS-800 test procedure.

There is no guarantee CSA C800 will be the consensus standard referenced by our legally binding codes or destined for broad adoption across jurisdictions. However, its methods are already being used explicitly in the manufacturing space. For example, in collaboration with CSA Group and using TS-800, Fluence held demonstrations in December 2024 to quantify the unit-to-unit fire propagation risks of their Gridstack Pro 2000.

CONCLUSION

With our wider community of stakeholders' perspectives in mind and with improved guidance from our code-makers and NRTLs on the horizon, we can continue to improve how we measure, evaluate, and anticipate off-gas and explosion risks with clearer testing and maintenance requirements. As OEMs adapt product designs to align with an evolving understanding of off-gas risks, a larger selection of BESS system options carrying reduced off-gas and explosion risk could give AHJs, owners, and engineering, procurement, and construction (EPC) companies greater confidence too. ■

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TYSON BITTRICH *joined Mayfield Renewables, Inc. in 2023, and he is currently a Market Research Analyst, helping lead initiatives in education curriculum development and microgrid feasibility modeling. Bittrich is a member of the Sustainable Energy Action Committee's ESS Standards Working Group. He holds an MA in philosophy and will graduate with a BS in renewable energy engineering from Oregon Tech in June 2025.*

NFPA 915-BASED REMOTE INSPECTIONS –

INSPECTORS ADD ANOTHER TOOL TO THEIR BELT

BY COREY HANNAHS, *National Fire Protection Association*

Building inspections serve as a crucial safeguard and often the last line of defense against risks associated with shoddy workmanship that fails to adhere to code requirements. Every day, jurisdictions across the country are putting their best foot forward to help ensure the safety of the citizens in their communities. But like many other professions, resources can be limited.

RECOGNIZING THE NEED

Back in 2017, an *NFPA Journal* article titled "Verified via Video," Jim Muir, then Clark County, Washington's chief building official, spoke about overcoming the limited resources his department faced post-recession, as well as other challenges including the geographic footprint of their county, and how they were starting to think outside of the box in trying to complete their growing list of inspections. Although many were initially apprehensive, Muir and his staff began to take advantage of modern technology, slowly implementing video inspections where they were comfortable using it.

Many of the initial concerns had subsided by 2013, and Muir and his staff developed a system they referred to as Sherlock video inspections. Using remote video inspections as another tool in their belt, the department was able to navigate through shortages of time, resources, and manpower and meet the needs of their community.

In June 2017 at the NFPA Conference & Expo® in Boston, Muir shared the success he and his team were having using video inspections with the NFPA Building Code Development Committee where he was a member. The information was well-received, and the committee initiated a request to the NFPA Standards Council to explore creating a new technical committee to develop a standard for remote inspections.

On December 2018, the NFPA Standards Council approved the creation of the Technical Committee on Remote Inspections, chaired by Jim Muir, and the path to what would eventually become NFPA 915, *Standard for Remote Inspections and Tests*, was set forth.

DEVELOPING THE STANDARD

Much of the development of NFPA 915 navigated through uncharted waters, complicated by the fact that technology for remote inspections was constantly changing. The initial draft of NFPA 915 began in August 2019 and was completed in May 2020.

You might recognize these dates as overlapping a significantly challenging time in the world. The

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COVID-19 virus first emerged in Wuhan, China, in December 2019, and the first documented case in the United States was reported in January 2020. While shortages of time, resources, and manpower were already reason enough to develop a standard for remote inspections, the unique aspects of social distancing due to the worldwide pandemic further escalated the need for NFPA 915, which could be utilized to perform inspections remotely while complying with social distancing to help keep individuals safe.

The initial draft of NFPA 915 was presented to the NFPA Standards Council at their August 2020 meeting, and the standard was approved to enter into its initial revision cycle, which would allow the public review required by the consensus-based NFPA Standards Development Process. As the proposed draft worked its way through the four-step process to become a standard, there was some irony in the fact that the NFPA 915 Remote Inspections Committee had to navigate through the development of the new document by meeting remotely. For the next two and a half years, the committee worked diligently through each stage of the process to produce the first edition (2024), which officially became an American National Standard made effective by the NFPA Standards Council on May 13, 2023.

ASPECTS OF THE STANDARD

Section 1.2 of NFPA 915 defines its purpose as providing minimum requirements for remote inspections and tests, automated inspection and testing, and distance monitoring to deliver an equivalent or improved result than what could be obtained with other inspection, testing, and monitoring methods.

For example, using remote inspection to review installed underground electrical conduits in a rural application could save driving time for the inspector and permit faster backfilling at the jobsite, reducing the opportunity for injury from someone falling into an open trench.

However, many municipalities looking to implement a remote inspection program simply didn't know where to start. NFPA 915 provides a wide array of information including general requirements, location and timestamp requirements, and technology use, as well as data collection, transmission, protection, retention, and ownership. Because NFPA 915 is an actual standard, it is written in enforceable language, but the document also provides some latitude around how it is used, which isn't common in other NFPA standards.

For example, the base enforcement rule found in Section 1.7 says that the standard shall be administered and enforced by the authority having jurisdiction (AHJ) as designated by the governing authority. While this is common in many enforceable standards, Section 1.7 is broken down into additional subsections that provide more latitude around enforcing the requirements of the standard.

- Initially, the AHJ is permitted to modify the requirements of NFPA 915 when permitted by the adopted governing laws, codes, regulations, and standards.
- There is an allowance for the AHJ to permit an approved independent third party to perform a remote inspection or test.
- Lastly, the AHJ can modify the NFPA requirements based on permission in writing by the owner or designated representative of what is being inspected provided that the intent of the standard has been met.

This unique enforcement latitude provided to the AHJ is based on the premise that those applying the standard can have very specific needs that must be malleable to properly complete the remote inspections.

NFPA 915 also provides additional freedom around new technologies. Technology has grown immensely over the last several decades. Flip phones have become smartphones where you can control nearly every aspect of your life. Floppy discs have become cloud storage. Trips to the store have become ordering on a phone app so what you need is on your porch the next day. The point is that technology is constantly changing, making adaptability key. Section 1.5.1 of NFPA 915 addresses this by stating that nothing in the standard shall be intended to restrict new technologies or alternative arrangements, provided that the level of safety prescribed by the standard is not lowered and is approved by the AHJ. If the level of safety expected by NFPA 915 can be maintained and is approved by the AHJ, new technologies are welcome to be used when performing remote inspections.

Roles

NFPA requirements address several roles that play a part in performing remote inspections. Chapter 4 covers the majority of the information pertaining to these individuals.

- The **property owner** is required to provide access to the areas necessary for remote inspections to be performed. It is also the responsibility of the property owner to provide safeguards to prevent capturing information that may be sensitive, such as unique aspects of manufacturing or other types of trade secrets. Another example might be a healthcare facility where patient information must be protected to protect personal privacy and avoid violating the Health Insurance Portability and Accountability Act (HIPPA), a United States law that protects individuals' health information while allowing for necessary access.

- The **contracto**r must obtain permission from the property owner in advance to utilize remote inspection as the means to properly verify the work that has been performed. The entity performing the remote inspection — commonly the contractor who completed the work — is the person physically on-site engaging with the AHJ while the remote inspection is being performed, often holding the recording device while being instructed by the AHJ. Regardless of who performs the inspection, they are required to have direct permission from the owner to access the property and perform the remote inspection.

If the inspection is performed by someone other than the AHJ, Section 4.3.2 provides several requirements that must be met, including a written inspection or test plan that must be submitted to and approved by the AHJ unless they exempt its requirement.

- The **AHJ** arguably has the most significant responsibility, including providing the following criteria for the remote inspection:
  - Suitability of performing the inspection or test remotely
  - Limitations
  - Documentation
  - Technology
  - Submission format
  - Scheduling requirements
  - Modifications
  - Record retention

IMPLEMENTING THE STANDARD

When it comes to building inspection needs, one size doesn't necessarily fit all. Based on the type of work being inspected, someone may be required to be physically onsite for a proper, safe inspection to be performed. But advancements in technology have created a new world of optional ways to perform a safe inspection.

CONCLUSION

In a world where resources to perform our jobs are becoming scarcer by the day, NFPA 915 offers a new opportunity to perform an inspection remotely, maximizing the use of resources while still ensuring the safety of our communities. As an NFPA 915 user, there are ways to use the standard's requirements to help shape your remote inspection plan while meeting your needs and comfort level. It doesn't have to be an all-in commitment right from the start. Perhaps it is initially used for reinspection to verify that a minor adjustment has been made. Then, as the comfort level with remote inspections increases, it can be extended to a growing number of applications.

As resources continue to decrease through funding and retirements of qualified staff and workload continues to grow due to the surge in construction, NFPA 915 is here as another tool in your belt to help ensure productivity. ■

NFPA 915 can be accessed via written publication or digitally through a subscription to NFPA LiNK®.

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COREY HANNAHS *is a Senior Electrical Content Specialist at the National Fire Protection Association (NFPA). In his current role, he serves as an electrical subject matter expert in the development of products and services that support NFPA documents and stakeholders. Hannahs is a third-generation electrician, holding licenses as a master electrician, contractor, inspector, and plan reviewer in the state of Michigan. Having held past roles as an installer, owner, and executive, he has also provided electrical apprenticeship instruction for over 15 years. Hannahs was twice appointed to the State of Michigan's Electrical Administrative Board by former Governor Rick Snyder, and he received United States Special Congressional Recognition for founding the B.O.P. (Building Opportunities for People) Program, which teaches construction skills to homeless and underprivileged individuals.*

ADVANCING CLEAN ENERGY:

HOW VOLUNTEERS SUPPORT SAFETY, OPERATIONS, AND STANDARDS INITIATIVES

BY JOSH ROGERS, *American Clean Power Association,* **and KEVIN ALEWINE,** *Shermco Industries*

Clean energy is no longer an emerging field but a cornerstone of modern power generation. While hydroelectric power set the stage for large-scale clean energy in the early 20th century, the industry today is defined by innovations in newer technologies such as wind, solar, and battery storage. Transitioning to these technologies has introduced new and unique safety challenges that demand robust safety protocols and a skilled workforce. Ensuring the workforce is well-prepared with advanced safety training and standards is crucial for developing a mature and expansive industry.

EARLY DAYS AND GROWING CHALLENGES

The clean energy industry began to expand significantly with the installation of wind turbines in the 1980s. At the time, electrical safety was understood conceptually but the industry lacked comprehensive standards, consistent training, and experienced supervision. Technicians faced various hazards, including electrical shock, arc flash, unguarded mechanical equipment, extreme weather, and working at heights — all while operating in small teams with limited oversight.

Today, with over 400,000 clean energy technicians in North America managing thousands of high-voltage transformers, substations, and other infrastructure, safety is a top priority. Organizations such as the American Clean Power Association (ACP), the Clean Energy States Alliance, OSHA, NETA, NFPA, CIGRE, and other stakeholders are leading the charge to improve workplace safety through collaboration, training, and the development of industry-specific resources utilizing primarily volunteer subject matter experts from the industry. Globally, other organizations such as the Global Wind Organization (GWO) are also working to standardize safety and training regimens to address these issues and develop training protocols and certifications.

Renewable energy generation sites offer unique challenges compared to many traditional generation and industrial facilities. Not the least among these are exposure to the elements, often extremely rural locations with limited medical or emergency services capabilities. Developing a culture of personal responsibility and adoption of a strong behavioral performance ethic is critical to both quality and safe operations.

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VOLUNTEERS' ROLES IN DEVELOPING SAFETY STANDARDS

Since its inception, ACP has developed guidelines, standards, and programs tailored to clean energy operations. In 2013, ACP's *Wind Project Operations and Maintenance Recommended Practices* established essential guidelines for wind site operations, offering the U.S. clean energy industry unprecedented direction. This foundational document highlighted the need for safety recommendations to ensure tasks were performed by qualified personnel.

In 2018, ACP adopted the Canadian Renewable Energy Association's (CanREA) Electrical Safety Program to address hazards specific to wind energy, particularly at 34.5 kV collector systems. This document emphasized the importance of arc flash awareness and technician-specific safety protocols.

CanREA is an independent organization focused on the renewable industry in Canada but shares documents and works closely with ACP and other organizations regarding safety initiatives. Safety tracks are always included in their operations conferences.

Additionally, the Energy Systems Integration Group (ESIG) has developed a set of operational guidance recommendations and hosts operator's conferences on performance excellence.

Although the National Renewable Energy Lab (NREL) is a government organization, it utilizes a broad base of volunteers focusing on reliability improvements. All these organizations have safety in mind, but there is little focus on safety as an event or topic of concern.

Over the past few years, safety concerns have expanded to include solar and battery energy storage systems (BESS). Each technology presents unique challenges, from arc flash risks in solar operations to fire safety concerns in BESS. Offshore wind projects add additional layers of complexity with the need to incorporate maritime safety. Lithium-ion batteries have become ubiquitous in an array of applications around the world, even as safety concerns remain. New research efforts, as well as a proposed NFPA battery code, hope to close the gaps.

Other standard-developing organizations including CIGRE, IEEE, and GWO are all working tirelessly to publish standards that help companies keep up with these ever-expanding technological breakthroughs.

The Solar Energy Industries Association (SEIA) recently announced a set of industry standards in development including technician training, and it is expected that some safety training and processes will be included in their standards.

ADVANCEMENTS IN TRAINING AND STANDARDS

To meet the demands of a growing industry, ACP has developed a range of training programs and standards. This multi-level technician development framework ensures workers are equipped with the skills and knowledge for their roles, whether in wind, solar, or battery storage.

Other organizations including CanREA, ESIG, SEIA, GWO, NFPA, and NETA, plus NETA's Corporate Alliance service partners offer extensive virtual and on-site training opportunities to prepare workers to safely do their jobs.

Recognizing the ongoing need for workforce development, the non-profit Clean Power Institute (CPI) was recently established to connect clean energy companies with the appropriate content and access to training centers providing entry-level technicians with standardized technical training and safety programs, ensuring the workforce remains prepared as the industry grows.

Other critical safety and training publications:

- NETA's Qualified Electrical Worker (QEW) Program for Wind Operations
- NETA's Qualified Electrical Worker (QEW) Program for Solar PV Operations
- NETA's Qualified Electrical Worker (QEW) Program for Battery Energy Storage Operations
- ACP Guidelines for Entry-Level Wind Technician Training
- ACP Guidelines for Entry-Level Solar PV O&M Technician Training
- ACP Guidelines for Entry-Level Battery Energy Storage (BESS) Technician Training
- Micro-credentials

ACP has also released ANSI standards such as:

- ANSI/ACP 1000-2.1-2023 Rescue And Fall Protection Standard: Definitions And Nomenclatures
- ANSI/ACP 1000-2.2-2023 Rescue And Fall Protection Standard: Rescue Training Requirements
- ANSI/ACP 1000-2.3-2023 Rescue And Fall Protection Standard: Fall Protection Training Requirements
- ANSI/ACP 5000-1-2022 Wind Workforce Definitions
- ANSI/ACP 5000-2-2022 Wind Technician Entry-Level Minimum Standard

These resources are complemented by annual safety outreach campaigns, including webinars, videos, and toolbox talks on topics such as electrical safety, driving safety, and prevention of severe incidents (SIFs).

ANNUAL SAFETY CONFERENCES

With the increasing awareness of the need for coordinated safety recommendations and standards, the ACP is committed to an annual operations, maintenance, and safety conference dedicated to safety and expanded to include operationsl excellence and quality as the topics are closely related. Many industry-changing initiatives continue to grow out of the working groups that meet during the event. Safety standards, workforce development, and operational issues are addressed and guidance documents — standards, white papers, and recommended practices — are developed by these teams.

NETA's annual PowerTest conference brings together the brightest minds in the electrical power systems industry and offers a platform to learn, share, and grow. PowerTest's technical sessions and hands-on demonstrations focus on the importance of understanding and implementing the latest safety standards while using the latest electrical testing technology, alongside other key topics that drive the future of our industry.

SEIA's large and growing industry exposition, RE+, attracts thousands of industry professionals, and it is hoped that a safety track will soon become part of their technical offerings during the event.

NFPA's Conference & Expo offers near-endless educational opportunities and innovative products on topics from fire prevention, wildfire preparedness, and electrical safety to hazardous materials, building and life safety, community risk reduction, and public safety.

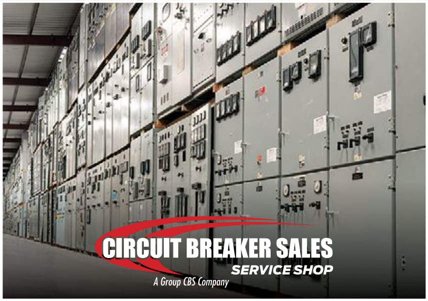
A COMMITMENT TO SAFETY

OSHA requirements extend to wind turbines where arc flash requirements, subject to NFPA 70E, were not initially in place as the turbines were mostly developed and tested in Europe, but now are accepted practice and, even with the new enforcement of the NFPA 70B maintenance requirements, needs still exist for additional documentation, offering good opportunities for staff development curriculum.

As the clean energy sector expands — and adds jobs at twice the national average growth rate — it faces an increasing responsibility to maintain and refine safety standards and support the technicians. By leveraging the resources and expertise of volunteers, the industry is poised to continue its trajectory toward greater safety and operational excellence. Trade organizations and events that do not highlight safety concerns and solutions should consider the critical needs of the industry and the people who work in these dangerous conditions every day. ■

JOSH ROGERS *is the Senior Director of Safety, Workforce Training, and Operations at American Clean Power (ACP). In this role, he leads the ACP team and committees focused on worker safety, workforce development, and operational excellence that will support renewables industry growth. Rogers spent several years as Director of Solar Operations for Duke Energy and developed standards, training, and operational leadership for leading companies including ABB, Sun Edison, First Solar, and Fluence. Prior to joining private sector energy companies, he served in the United States Navy for nine years where he was certified as a nuclear operator and Master Training Specialist. Rogers earned his BS in technology from Excelsior University.*

KEVIN ALEWINE *is Director of Renewable Energy Services at Shermco Industries with a focus on business development in the wind-energy business sector. He has extensive global experience with the application of electrical insulation materials, systems, and processes for the manufacture and repair of electrical machinery. Kevin formerly chaired the American Clean Power Operations and Maintenance Committee developing recommended practices for wind-energy asset maintenance. Additionally, Kevin was the General Chair of the 2019 IEEE Electrical Insulation Conference and is a member of the IEEE Dielectric and Electrical Insulation Society Administrative committee.*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