Safety is the inspiration for all of the Grace Engineered Products. We are experts at designing products that manage electrical environments so the job can get done in the safest and quickest manner. We continually challenge our products and the work process to be better, safer and more controlled. The number of uniquely designed components grows daily... there are an infinite number of possibilities. By sharing these technical white papers we want to explain our products, our designs and our drive to keep getting better, to be safer.
Abstract – The NFPA 70E raised the standard for electrical workplace safety and fundamentally transformed methods regarding electrical and mechanical maintenance, and troubleshooting. These higher safety standards have inspired improvements to electrical system designs that increases both uptime and productivity, and reduces workers’ exposure to arc flash and shock hazard risks. End-users continue to challenge electrical professionals to develop ways to better maintain energized or de-energized electrical equipment in accordance with NFPA 70E. As a result, many end-users have installed Permanent Electrical Safety Devices (PESDs), which allow for thru-door voltage verification without voltage exposure, on the outside of energized electrical equipment making them safer and simplifying mechanical and electrical lock-out/ tag-out procedures (LOTO).

With Permanent Electrical Safety Devices (PESDs), workers can access the inside of the panel in a de-energized state without voltage exposure; a method which not only meets but exceeds the requirements of NFPA 70E 120.1(1-6)/CSA Z462 4.2.1. PESDs are, essentially, the PPE you don’t wear, and provide necessary barriers between personnel and voltage. Because workers are on the outside of the panel, PESDs decreases the opportunity for arc flashes and shock incidents, which is the crux of NFPA 70E/CSA Z462.

Index Terms: Permanent Electrical Safety Devices, NFPA-70E, Voltage detection, Safety Device

I. Introduction

Permanent Electrical Safety Devices (PESD) are an electrical component(s) hardwired to a source of voltage(s) and installed into electrical systems enabling workers to validate zero electrical energy without being exposure to voltage. The PESD inherently minimizes arc flash and shock hazards because they reduce voltage exposure, provide voltage labeling on all sources and 24/7 visual and/or audible indication of voltage. Fig.1 shows an example of the Voltage Source Labels on a panel fed with 3-Phase 480VAC and 120V separate control. The PESD is mounted on the outside of the panel provides workers with the ability to determine all possible sources or electrical supply [1]. The use of a PESD can enhance safety procedures because workers have to perform a physical action(s) in addition to audible and visual voltage indications using a Non-Contact Voltage Detector. The Non-Contact Voltage Detector (NCVD) is a battery operated voltage detector pen that senses AC voltage without actually touching an energized conductor (50-1000VAC).

Either three phase or single phase source(s) can be extended to the outside of an electrical enclosure through an encapsulated non-conductive housing called a Voltage Portal. The Voltage Portal is designed for use with a NCVD to sense voltage. The NCVD will detect the presence of voltage when it is placed into the voltage portal. Fig 2 outlines the fundamental concept of a Voltage Portal and associated NCVD.

Alternatively a Light Emitting Diode (LED) type Voltage Indicator can be permanently hardwired to the phase(s) and ground. This device will illuminate when a voltage greater than 40VAC/30VDC is applied or when a deferential exists between two lone inputs.

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The typical requirements for 3-phase/4-wire Voltage Indicator include:

- Powered from the line voltage (no batteries)
- Wide operating AC/DC voltage range (40-750VAC/30-1000VDC)
- High surge immunity
- Meets 50 volt threshold as per NFPA 70E 110.6 (D)(1)(b), 110.7(E)
- Cat IV and UL Certified to UL 61010-1 as per NFPA 70E 120.1(5)

Informational Note.

Another useful indication system is a Zero Energy Fiber Optic Voltage Indicator. These types of indicators provide the same functionality as voltage indicators but they utilize non-conductive fiber optic cables that transmit visible light indication of the internal presence of voltage. With this system no voltage is brought to the outside of the enclosure or switchgear. Fig. 3 illustrates the use of a three phase voltage indicator mounted close as possible to the main disconnect with the leads routed away from high energy equipment that may affect the operation of the NCVD.

Improved safety builds upon time-tested safety principles. For years the precise language of NFPA 70E 120.1 has provided maintenance workers with a fundamental methodology for establishing zero electrical energy. Armed with portable voltmeters, workers have always depended on this single device as the primary means of proving the presence or absence of electrical energy in an electrical enclosure. Recently, workers discovered that PESDs, which are built into the electrical system and designed solely to indicate voltage, have significant advantages independent of the solo, portable voltmeter. The relatively new concept of PESDs improves the workers’ ability to safely isolate and locate electrical energy beyond that which was originally conceived when Article 120.1 was written. With this said, workers should use PESDs as their primary instrument for detecting voltage and their voltmeter as their secondary instrument. With PESDs installed correctly into electrical enclosures, incorporated into safety procedures, and validated before and after each use, workers can transition the once-risky endeavor of verifying voltage into a less precarious undertaking that never exposes them to voltage. The visibility of PESDs on the enclosure exterior provides workers with the ability to “determine all possible sources of electrical supply” (NFPA 70E 120.1(1)) feeding the enclosure. Electrical safety has been radically improved by eliminating exposure to voltage while using PESDs to validate zero electrical energy, which complements the existing, proven practices without replacing them.

Using PESDs in an electrical safety program requires written lock-out/tag-out (LOTO) procedures. Employees need to be trained and have access to these procedures.

II. Process of Validating and Testing Instruments

An electrically safe work condition requires 100% accuracy from voltage testing instruments. To ensure this, the NFPA 70E indicates that before and after each test, determine that the voltage detector is operating satisfactorily, (NFPA 70E 120.1(5)). Validation means that electricians first check their voltage testing instrument to a known voltage source (i.e. a nearby 120VAC outlet). Next, they check for zero voltage on the primary source. Work begins only after the voltage testing instrument is rechecked to the independent live voltage source. This straight-forward validation procedure works for a portable voltage detector because it can be physically moved between two voltage sources, but the same principle applies to PESDs. Over the past several years, PESDs have become a substantial way for companies to increase safety and productivity at the same time.

Fig. 4 illustrates the steps in the process of verifying voltage with a voltmeter. A voltage measuring instrument validates actually presence of voltage by displaying the voltage, while a Voltage Indicator alarms when voltage is within its range. A small current flow through the voltmeter is the way voltage is measured.
One large forest products company in the Northwest region of the United States started using the voltage indicator PESDs in 2004 and quickly incorporated them into other facilities. The Manufacturing Services Manager for this company has indicated that the use of the fixed voltage indicators would allow us to avoid opening starter or disconnect compartment doors for approximately 75% of all lockouts.[3] The same principles absolutely apply to other PESDs; however, because a PESD cannot be moved between two voltage sources, the technique for validation needs a slightly different approach.

So what actually needs to happen to validate any voltage testing instrument? Testing for voltage simply requires a small amount of current to flow between the two voltage potentials. The voltage detector circuit determines a voltage potential by relating this current flow to actual voltage and providing the worker an appropriate indication (audible, visual or digital display) (Fig. 4).

A. Validating a Voltage Portal & NCVD Combination

A NCVD determines if voltage exists in a conductor by creating a low current capacitive circuit between the conductor, the NCVD, the worker, and ground (Fig. 5). Therefore, when the NCVD is positioned close to a live conductor, this completed circuit causes the NCVD to beep or flash telling the worker that voltage exists in the conductor.

For a NCVD to function, a high capacitance ground path is established through the worker. When the panel is energized, the worker tests and verifies both the NCVD and the ground path through the worker. The permanent location of the three phase voltage portal requires the worker the stand in the same location (or same ground path) every time the NCVD is used. Fig. 5 illustrates the ground path.[4]

Because voltage portals mount permanently to the outside of enclosures, the worker has to stand in the same place when using his NCVD. This makes this capacitive circuit more reliable and more repeatable than it would be when workers use a NCVD in all other application because the environment is always the same and doesn’t change. Since NCVDs are portable, they can also be checked to an independent voltage source as per NFPA 70E 120.1(5).

Workers using NCVDs understand that since a NCVD isn’t physically hardwired to the voltage source, their operation can be influenced by external conditions such as electrical noise and proximity to ground. Those influences are greatly reduced by 1) where the voltage portal is mounted and 2) how the lead wires are routed within the enclosure. The fact that a voltage portal and the worker are always in the same location every time means reliability increases.

Installing voltage portals as close as possible to the enclosure flange by the main disconnect and routing the lead wires away from other devices creates a more reliable installation.

Fig. 6 shows the proper locating of a three phase voltage portal close to the main disconnect and routing the lead wires away from any devices inside the enclosure that generate a lot of electrical noise increases the overall reliability of the NCVD voltage indication. Mounting PESDs on the enclosure flange makes the lead wires less susceptible to damage.

B. Validating a Voltage Indicator

A hardwired voltage indicator brings up two interesting issues. First, it is hardwired and you can’t move it to an independent voltage source. Second, adding a switch to toggle between the line voltage and the test voltage adds more components and complexity, which leads to unreliability. This is impractical because it requires a 600V fused three-pole double throw relay. The fusing, the relay wiring, and switching introduces 18 connections (failure points) between the voltage source and the voltage indicator. Since the sole purpose of the voltage indicator is to indicate voltage, anything installed between the source voltage and the voltage indicator increases the chance of a false negative voltage reading - switches, relays and fuses included. (Note: A false negative is when voltage exists in a conductor and the voltage detector doesn’t sense it).

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Third, because of the 3-phase circuit design, a voltage indicator accommodates six current paths (Fig 7) between phase(s) and ground, thereby reducing the number of possible failure modes. In one possible circuit design, before a single LED illuminates, the current must pass through at least four LED flashing circuits. “Voltage when illuminated,” as per the warning label, means if only one of the four LEDs illuminates; it still provides voltage indication to the worker. Validating this device requires it be checked for proper operation before and after each LOTO procedure and that the solid ground connection is checked upon installation so it will alarm on a single phase condition caused by a failed isolator.

III. Multi-Meters Compared to PESDs

The design of a typical voltage indicator is considerably different from a multi-meter because it has six possible current paths through four connected voltage detection circuits as per Fig. 7. When AC voltage is applied to this device, current must pass through two voltage detection circuits before the LED pairs illuminate. This means that current must pass through 4 LED’s when indicating voltage. Each LED pairs illuminate on the (+) and (-) side of the AC sine wave.

Until PESD systems came along, creating electrically-safe work conditions relied solely upon the portable multi-meter. This tool is not only used in electrical safety, but has features making it invaluable for other purposes such as electrical troubleshooting and diagnostics. On the other hand, a PESD leaves no question or confusion when a worker uses it in creating an electrical safe work condition because it was designed, built, and installed for a single purpose—voltage indication for electrical safety. Understanding these differences help determine an acceptable validation procedure for PESDs and show how they exceed the validation requirements of NFPA 70E 120.1

IV. Validating Voltage Indicators and Voltage Portals

Voltage indicators and voltage portals, as shown in Figs 8 and 9, are complementary because their strengths and weaknesses offset each other. Let’s consider the primary voltage testing instrument to be the voltage indicator because it provides the hardwired connection to the voltage source as required by NFPA 70E 120.1(5). Then the NCVD/voltage portal becomes the testing device for the voltage indicator. Both devices can be checked before a LOTO procedure to ensure proper operation while the control panel is energized (Chart 1). The traditional method of validating the voltage indicator to an independent voltage source is met with the NCVD/voltage portal combination. On the other hand, it can be argued that a voltage indicator by itself cannot be validated by the traditional method. However, because permanently-mounted voltage indicators are designed to only detect voltage, the built-in advantages over a simple multi-meter needs to also be considered in validating this device.

V. Written Loto Procedures and Mechanical LOTO

A PESD becomes a “real” safety device only after it is included as part of a written LOTO procedure. Without this, PESDs are nothing more than just another electrical component. The LOTO procedure must explain to the worker each step in the LOTO procedure that involves the PESD. At a minimum, workers will need to verify proper operation of the PESD before and after performing a LOTO procedure.

As demonstrated in Fig. 8, when the control panel is energized, the worker verifies proper operation of the voltage indicator and the NCVD and its associated ground path through the worker.

Interestingly, the mechanical maintenance workers receive a huge benefit with PESDs when these devices are used in mechanical LOTO procedures. Workers performing mechanical LOTO (work involving no contact with conductors or circuit parts) procedures must still isolate electrical energy. PESDs provide a means of checking voltage inside an electrical panel without exposure to that same voltage. Without these devices, a mechanic performing mechanical LOTO would be required to work in tandem with an electrician using a volt meter to physically verify zero voltage inside an electrical panel before work begins. In this case, the electrician is exposed to voltage. With PESDs, the mechanic can single-handedly check for zero electrical energy without any exposure to voltage, thereby making the LOTO procedure safer and more productive.
SAFER LOCK-OUT TAG-OUT

A Pennsylvania plant reduced their electrical maintenance staff down to one electrician during the day shift. To increase efficiency, the second and third shift operators began performing limited mechanical maintenance. By rewriting their LOTO procedure, installing voltage portals on each motor control center bucket, and training the operators to use non-contact voltage detectors with the voltage portals, the off-shift operators were able to perform the maintenance tasks that still complied with OSHA LOTO requirements [2].

VI. Reduced Arc Flash Risk and Personal Protective Equipment (PPE)

When workers can determine a zero electrical energy state without any voltage exposure to themselves; their electrical safety program is safer. Verifying the proper operation of a meter and testing for absence of voltage before working on an electrical conductors (“Test before Touch”) for all practical purposes should always remain a habitual practice for workers. The goal of PESDs is to ensure that when workers ‘test before touch’, that they test only de-energized conductors.

Fig. 9 shows a NCVD being used to verify that proper operation of the voltage indicator. This is a secondary test for the absence of voltage.

Without PESDs, a failure of an isolator may go undetected until the electrician discovers live voltage after opening the panel. This exact scenario is a common cause of arc flash. A direct short circuit may result from one misstep by the electrician while checking voltage. Even worse yet, the electrician would take a direct hit in the face from the resulting arc flash. Because PESDs meet NFPA 70E 120.1 and the lessened risk of voltage exposure, some will conclude that once the panel is open the need for personal protection equipment (PPE) is also reduced. Whether or not you agree with this, voltage detectors are a low-cost, redundant voltage verification tool that reduces arc flash risk, increases safety, and adds productivity at a low installed cost.

VII. Conclusion

The precise language of NFPA 70E 120.1 has provided maintenance workers with a fundamental methodology for establishing zero electrical energy. Portable voltmeters have been what workers depend on as the primary means of proving the presence or absence of electrical energy in an electrical enclosure. However, the advantages of PESDs as the primary instrument for detecting voltage are abundant in that they improve the workers’ ability to safely isolate and locate electrical energy beyond that which was originally conceived with Article 120.1.

VIII. References

[1] NFPA 70E, 2012 Standard for Electrical Safety in the Workplace 120.1(1)
[2] OSHA 29 CFR 1910.147 and 1910.333(b); NFPA 70E, 2012 Standard for Electrical Safety in the Workplace 120.2(B)(2), 120.2(C)(1)

IX. VITA

Phil Allen is the President and owner of Grace Engineered Products, the leading innovator of permanent electrical safety devices. He holds two US Patents, a power receptacle design and a voltage detector test circuit. His passion is finding new and more efficient ways of bringing electrical safety to the forefront. Phil did his undergraduate work at California State University, San Luis Obispo and is a 1984 graduate with a BSIE.
# X. Appendix

## PESD Truth Table for Establishing Zero Electrical Energy (3-Phase System)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Primary – Voltage Indicator</th>
<th>Comments</th>
<th>Secondary – NCVD and 3Ø Voltage Portal</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Three Phases Energized</td>
<td>Ground connection on GRD leg</td>
<td></td>
<td>Alarms when inserted into the voltage portal</td>
<td>Ground path</td>
</tr>
<tr>
<td>One or Two Phase Energized (failed isolator or blown fuse(s))</td>
<td>GRD leg must be verified upon installation</td>
<td>If no ground connection exists, the voltage will not indicate on a single phase condition, therefore the NCVD-voltage portal would provide a redundant voltage test.</td>
<td>Alarms when inserted into the voltage portal (typically not phase sensitive)</td>
<td></td>
</tr>
<tr>
<td>All Three Phases De-energized</td>
<td>No LEDs illuminated.</td>
<td>No indication or alarm from NCVD</td>
<td>NCVD verified to another voltage source after testing for zero voltage</td>
<td></td>
</tr>
<tr>
<td>Stored Energy (AC or DC)</td>
<td>Illumination of any single LEDs indicates voltage</td>
<td></td>
<td></td>
<td>See Fig. 6</td>
</tr>
</tbody>
</table>
Abstract – The Risk Control Hierarchy (RCH) in the ANSI-Z10 standard provides electrical safety professionals with an excellent roadmap for setting the right safety objectives that result in the reduction of electrical risks. Combining our understanding of electricity with our principles of safety is the key to improving electrical safety. For example, when a Department of Energy electrical safety program is analyzed under the light of the RCH, many potential electrical safety improvements begin to jump off the page. The RCH not only helps improve a plant electrical safety program, but it also inspires manufacturers to improve their electrical equipment designs. Lastly, the RCH provides a means to measure the effectiveness of an electrical safety initiative much the same way a project manager uses financial measurements (Return on Investment or Payback Analysis) to evaluate a project.

1. Introduction

In the late 1880s, a young boy was electrocuted when he accidentally touched an unlabeled, energized telegraph wire. That incident ignited an inventor by the name of Harold Pitney Brown to make an impassioned plea in a New York Post editorial to limit telegraph transmissions to what he considered a safer level of 300 Volts. Perhaps Harold thought that limiting electrical transmissions to levels of 300 Volts or less would provide instant electrical safety. With over 120 years of hindsight, we view things much differently today. Yet, Harold stumbled across two important concepts. The notion of “300 Volts” is a technical discussion about the laws of electrical energy (Ohm’s Law, etc) that lends understanding to how electrical energy can kill or maim. On the other hand, the term “safe” reflects a working knowledge of the fundamental principles of safety.

Our challenge is to combine our technical understanding of electricity with the principles of safety to ensure electrical safety is both practical and effective. The better we understand both concepts the greater the likelihood we will have to improve the status quo. The Risk Control Hierarchy (RCH) does an excellent job in blending these two key concepts.

2. Risk Control Hierarchy

The heartbeat of safety is the Risk Control Hierarchy (RCH), which is found in Appendix G of the ANSI Z10 Standard. The RCH helps us prioritize safety initiatives from least effective to most effective. For example, will you be safer wearing a helmet while riding a motorcycle or by selling it altogether? Obviously, selling the motorcycle eliminates the risk of an accident, while wearing a helmet offers protection to your head from the risk of a head injury during an accident. The RCH works by helping us rank risk reduction measures from most effective to least effective as per below:

1. **Eliminating** the risk.
2. **Substituting** a lesser risk.
3. **Engineering** around risk.
4. **Awareness** of every risk.
5. **Administer** and regulate behavior around risk.
6. **Protect** workers while exposed to risk.

Note that each step above is equally important, yet not equally effective in protecting workers. Eliminating a risk is the most effective way to keep workers safe while protection from a risk by using Personal Protection Equipment (PPE) is least effective. There have been great improvements in the design of PPE, but its primary purpose is keeping workers alive – not 100% safe.
3. Safety and Risk
Risk, which is defined as exposure to a hazard, is two-pronged. There is the probability of exposure and severity of potential injury. For example, a 120V outlet is a greater risk than a 13.8KV switchgear line-up because more people are exposed to the 120V outlet. Since risk is exposure to hazards, then safety is the reduction and management of risk. The management responsibility of an electrical safety program typically falls to an electrical engineer because he or she understands electricity. In our modern world we can never eliminate the risk, but are very good at finding new ways to reduce risk.

Another way to look at risk is the chart (Figure 2) developed by Ray Jones which shows the relationship between the worker and the safety infrastructure above him. A worker performing tasks must make many complex and specific the decisions that affect his safety. In the case of electrical safety, energy isolation is very personal for electricians facing deadly electrical energy every time they open a panel. By the time they touch electricity, it’s too late.

Electrical accidents are impossible without electrical energy. If an electrician comes into direct contact with electrical energy, there is a 5% fatality rate. Shocks and burns comprise the remaining 95%. The NFPA 70e is very specific on how to isolate electrical energy. First, all voltage sources must be located and labeled. Multiple voltage sources are commonplace today due to the proliferation of back-up generators and UPS’s. Next, voltage testing devices must be validated using the LIVE-DEAD-LIVE procedure. Additionally, the voltage tester must also physically contact the voltage and must verify each phase voltage to ground.

5. The RCH and Electrical Safety
How does the RCH apply to electrical safety?
1. Elimination – Removing all electrical energy exposure.
2. Substitution – Lowering the electrical energy exposure.
4. Awareness – Revealing and labeling all sources of electrical energy.
5. Administrative Controls – Regulations that teach personnel safety around electrical energy.

Electrical workers are exposed to the greatest risks at the lower levels of the RCH. Recognizing that these “residual risks” are present; the NFPA 70e tells workers how to perform their work safely in spite of these risks. In fact a large portion of the NFPA 70e details how to best manage these risks through Awareness, Administration, and Personal Protection. On the other hand, the greatest opportunity for risk reduction comes by focusing in the upper part of the RCH. Huge improvements in electrical safety will come by Eliminating Substituting, and Engineering solutions that manage electrical energy exposure.

6. The Department of Energy (DOE)
For better insight into the RCH process, let’s look at a 2005 Department of Energy report on their electrical safety record. This report cited six reasons for their 14.1 electrical incidents per month.

Within this DOE report, “hazard identification” [see Table 1 in Appendix A] stood out as an administrative control issue resulting in numerous electrical incidents. The solution was to get tougher administrators or look for improvements higher up in the RCH. Right above Administrative Controls (see Figure 1) we learn that increasing employee’s awareness of electrical hazards will reduce these types of incidents. A potential solution is to label and mark all voltage sources (hazards) feeding the electrical system. Voltage indicators and voltage portals wired to each voltage source provides two benefits: It identifies the voltage source and provides a means to check the status of that voltage source without exposure to voltage. Apply the same process to “LOTO violations”.

7. Elimination: The Hall of Fame of Safety
We can enter the Electrical Safety Hall of Fame by finding ways to eliminate voltage exposure. Here are a few practical examples that can be implemented today:
Risk Control Hierarchy

• Lock Out Tag-Out [LOTO]: requiring LOTO procedures electricians to verify zero energy before performing mechanical maintenance needlessly exposes workers to voltage. Since all voltages do not create mechanical motion, thru-door voltage checking devices as part of a mechanical LOTO procedure will eliminate voltage exposure (see Appendix B).

• Open a control panel? What maintenance functions can be moved to the outside of the panel? Thru-door data access ports are becoming commonplace because they allow programming with the panel door closed (Figure 3). A more recent unmanaged Ethernet switch mounted outside the panel. This unique device allows full thru-door access for a worker to troubleshoot and reset the Ethernet switch mounted outside the panel. This unique device allows full thru-door access for a worker to trouble-shoot and reset the Ethernet switch (Figure 4). What other device can be re-engineered around thru-door electrical safety? Perhaps putting certain branch circuit breakers on the outside of the panel is a good application?

• Control Panel Design: Providing a physical separation between the power and control compartments within an enclosure may become a standard. Voltages under 50 volts are considered safe, so reducing the control power to 24VDC makes the control power section safe to work on while it is energized. These above examples are only ‘scratching the surface’, so I challenge you to find ways to eliminate voltage exposure.

Harold Pitney Brown intuitively knew that eliminating risks would save lives. He just got one detail wrong when he thought that 300 Volts was not a risk. Now for the rest of the story: To prove that AC voltage is more lethal than DC, Thomas Edison hired Harold Pitney Brown to develop the first electric chair that executed William Kemmler on August 6, 1890. So much for electrical safety!

9. Thru-Door Voltage Checking and Labeling

A 40+ year industrial electrician once said, “I like anything that keeps me from getting bit [shocked]!” Getting a dog or snake bite is always a surprise! Since voltage is invisible, most electrical accidents happen because the electrician is unaware of a voltage source. Therefore using every possible means of marking every voltage source within an electrical enclosure will go a long way to limit these surprises. Let’s go a step further and make sure all voltage sources could be seen and tested from the outside of the electrical enclosure. This tells electricians the locations and the voltage states of all the electrical energy within an electrical panel.

10. Voltage Portals Improve Non-Contact Voltage Detectors

Within most of the common trades, many maintenance workers carry Non-Contact Voltage Detectors (NCVD) in their tool belts. Many times maintenance workers just need to know if there is power in a conductor. A NCVD is a simple, yet safe tool that checks voltage without physical contact with the current carrying conductor. When a NCVD is positioned close to an energized conductor between 90-1000VAC (50-500VAC), it beeps or flashes to indicate the presence of voltage. Still today many electricians carry sharpened voltmeter leads to stab into insulation to check the voltage when they can’t easily get access to the bare conductor.

11. Label and Check Voltage with Voltage Portals

A voltage portal is a single voltage point encapsulated into a non-conductive housing mounted to the outside of an enclosure. With this, workers can check voltage inside the enclosure with a NCVD without being exposed to voltage. What if every voltage source within an enclosure was wired to a voltage portal? Then workers would not only be able to see every voltage source, but check their status prior to working on the panel.

8. Conclusion

When safety works perfectly, nothing happens! When there is an incident or a close call the RCH should be an inspiration to find a better way. By applying the RCH principles to electrical safety risks, it will open our eyes to see more practical ways to reduce those risks. Perhaps, we would expend more resources finding electrical safety solutions that will provide both higher safety and productivity dividends.
12. A “False Negative” Is Deadly
Getting “bit” from live voltage is almost always a surprise! Far worse is an electrician starting to work on a conductor that he just tested “dead”, but actually is “live”. This is referred to as a “false negative” indication, which means that the voltage tester (falsely) indicated that there was no voltage (negative). The opposite scenario is a “false positive” which never hurt a soul. Because of this, NCVD’s have not been considered a reliable means in determining electrical isolation.

NCVD’s are a bit mysterious and because of the possibility of a false negative reading, some plants won’t allow maintenance workers to carry them. The following list details the many factors that affect the operation of a NCVD:

- AC only
- Minimum voltage level
- Phase cancellation
- Metal barriers (small enclosures)
- Underground cables
- Hand position
- Temperature
- Induced voltage
- Frequency

13. How it Works
Figure 7 shows a typical NCVD checking a wire for voltage. When the NCVD is positioned next to an energized conductor, two capacitive circuits are created. A smaller capacitance exists between the energized conductor and the NCVD, while a larger capacitance exists between the NCVD through the worker’s body to ground. If voltage is applied across a capacitor, then the voltage drop across a small capacitor is bigger than the voltage drop across a big capacitor. By comparing both of these voltages, the NCVD decides if the wire is energized. However, because this circuit is somewhat sensitive, other electrical energy within an enclosure will change the effective capacitance and ultimately the operation of NCVD. A false-negative reading is the worst case scenario when this stray “parasitic” capacitance changes too much the overall capacitance circuit. However, if we can test that a completed electrical circuit exists then we will know that the conditions are ripe for the NCVD to properly sense voltages.

14. Testing Voltage Portal / Panel Combination
Once voltage portals are installed into a panel, they become the only permanent location on the outside of the panel where maintenance workers check voltages with NCVD’s. The correct design and installation of a voltage portal inherently limits the effects of parasitic capacitance and the opportunity for a false negative reading. For example, to insure consistent and reliable voltage readings, the three voltage portals shown in Figure 8 are mounted to the side of panel with the wires routed away from other energized conductors.

Next, the control panel gets installed permanently into a facility. Once this is done, the capacitive circuit from the control panel to ground must be verified for a NCVD to reliably indicate voltage. Therefore, the entire voltage portal-panel combination can be tested as part of a written LOTO procedure to verify that a reliable capacitive circuit to ground exists when the control panel is energized.

15. What is a Voltage Indicator?
The shocking truth is that voltages only become hazardous if you are able touch the live conductors (over 50Volts). A voltage indicator resides on the outside of an electrical panel and provides maintenance people the ability to see the voltages without opening the panel. Simply put, a voltage indicator is like a permanently connected voltmeter that personnel can see all the time. Seeing voltage through closed doors is a very safe idea.

Surprisingly most low voltage (under 600V) fatalities occur at 120V. Therefore in order for a voltage indicator to be truly effective in electrical safety, it must be able to indicate voltage between 50V and 600V. Furthermore, since most electrical systems have three-phases, a voltage indicator must be able to alert workers to voltage on any of the three phases. Therefore, a typical 3-phase voltage...
Risk Control Hierarchy

A voltage indicator puts a redundant layer of protection between an electrician and live voltage. The ability to “pre-check” voltage before opening an electrical enclosure means that workers significantly reduce their exposure to voltage and offer these safety benefits:

- Reduction in arc flash incidents due to voltage checking.
- Saves time due to simplified LOTO.
- Checking voltage with a meter is the 4th leading cause of arc flash incidents.
- A voltage indication is a permanently wired 3-Phase 24/7 “Voltmeter” with a 20+ year life.
- Voltage indicators are self-powered from the line voltage, requires no batteries, and no maintenance.

By the time you physically contact raw electrical energy, most often it is too late. A thru-door voltage indicator offers a much needed level of safety over and above the traditional voltmeter and proper safety procedures.

16. Benefits of Combining Voltage Portals With Voltage Indicators

Both voltage indicators and voltage portals provide an independent means of checking voltage from the outside of an enclosure. Furthermore, these devices add less than $160 to the cost of a panel. Under current NFPA 70e regulations accessing potentially live panels has become time consuming. Using through panel voltage checking devices reduces risk of arc flash and shock and saves time. Note the comparison on Table 2.

17. Mechanical Lock-Out Tag-Out

Mechanical maintenance procedures require isolation of all energy sources (including electricity) before work begins on the piece of equipment. A typical procedure requires an electrician to access the live voltage section of the equipment to verify zero voltage. Since a vast majority of electrical energy is converted into mechanical motion, the presence of voltage does not automatically guarantee mechanical motion because motors need a very specific power input for rotation to occur. For example, a three phase motor rotates only when it receives enough current and the correct voltages on all three phases.

All voltages do not create mechanical motion. Furthermore, control systems are designed to determine not only when a motor starts and stops, but if it is safe to do so.

Raw electrical energy has the ability to instantaneously cause shock injuries and damage to equipment in the event of an arc flash explosion. When electricity is confined within a mechanical system, it is inherently safer due to the system design. While 100% electrical isolation is beneficial for mechanical LOTO, it is not required to make a system mechanically safe. Therefore, a voltage indicator used in conjunction with proper procedures offers a reliable means to verify zero energy state for mechanical maintenance. No longer is an electrician put at risk to physically verify a zero electrical energy state prior to maintenance. A voltage indicator is a very simple device because it only indicates voltage, and therefore any worker is able to verify zero (less than 40VAC) energy prior to performing mechanical maintenance.

References

- 3 - Ray Jones was Chairman of the 2000 Edition of the NFPA 70E
- 4 - In this procedure, the voltage tester is checked to a known “live” voltage source, then checked to make sure that the panel is “dead” and lastly retested to another “live” voltage source to make sure the tester is still functioning.
- 5 - NFPA 70E (2009) 120.1(5), Annex G 3.4
- 6 - Mechanical LOTO
- 7 - Worker Death by Electrocution (Figure 10) NIOSH Publication No. 98-131; http://www.cdc.gov/niosh/docs/98-131/epidemi.
- 8 - In a three phase system, a motor would not rotate if one phase was energized.

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### Appendix C

#### Table 1

<table>
<thead>
<tr>
<th>Causes of Incidents</th>
<th>Present RCH Principle</th>
<th>Increased Risk Reduction RCH Principle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of hazard identification.</td>
<td>Administrative</td>
<td>Properly administering NFPA 70e requires all electrical enclosures to have warning labels with incident energy level (calories).</td>
</tr>
<tr>
<td>LO/TO violations including shortcuts or lack of energy verification.</td>
<td>Administrative</td>
<td>Can the LO/TO procedure be rewritten to reduce exposure to voltage?</td>
</tr>
<tr>
<td>Reducing electrical energy to Cat 0/1 will greatly reduce the potential arc flash energy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marking all energy sources on the panel exterior provides personnel with simple yet safe hazard identification.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thru-door voltage pre-checking “eliminates” all exposure to voltage for mechanical LOTO* and provide significant risk reduction for electrical LOTO.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lowering the arc flash energy effectively ‘substitutes’ for a lower risk for a higher risk.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Table 2

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Multi-function</th>
<th>Voltage Only</th>
<th>Voltage Only</th>
</tr>
</thead>
<tbody>
<tr>
<td>Powered by</td>
<td>Batteries</td>
<td>Passive/Batteries</td>
<td>Line Voltage</td>
</tr>
<tr>
<td># of Phases</td>
<td>Single</td>
<td>3-phase/Single</td>
<td>3-phase</td>
</tr>
<tr>
<td>Hardwired</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Thru-Door</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Indication</td>
<td>Digital</td>
<td>Visual/Audible</td>
<td>Visual</td>
</tr>
<tr>
<td>Physical Action</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Live-Dead-Live</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
</tr>
</tbody>
</table>
**Reduces Arc Flash & Increases Safety**

A SafeSide® voltage indicator is a pushbutton-sized electrical safety device mounted to the outside of any electrical enclosure and wired internally to the primary incoming power source. The sole purpose of this device is to alert workers to the presence (or absence) of voltage with flashing LED’s. Electrical safety is enhanced by properly applying voltage indicators and correctly incorporating them into an electrical safety procedure. The NFPA 70E impacts every aspect of workplace electrical safety, thereby providing maintenance personnel with a steady stream of new ideas, better procedures, and improved tools for electrical personnel. Electricians still rely on the good ‘ol voltmeter to determine if an electrical system has been put into an electrically safe condition. A voltmeter and SafeSide™ voltage indicator each have different yet similar functions, but still belong on the same “electrical safety” team. Let’s compare and contrast both devices with the goal of understanding how each device can be used for maximum safety.

**A SafeSide® Voltage Indicator:**
- is permanently mounted and less susceptible to damage.
- has built-in reliability due to redundant circuitry, surge immunity, long life LEDs and heavy duty construction.
- has but one function, indicating voltage.
- gets its power from the line (hazardous) voltage, not from an external power source.
- is hardwired with pigtail leads which ensures a reliable connection.
- works well within a mechanical Lock-out Tag-out procedure.
- requires no fusing and easily installs in a 30mm hole.

**A Voltmeter:**
- Portable Tool: Shorter life-span & susceptible to damage
- Multiple functions: Test device for AC/DC voltage, OHM’s
- Powered when use: ON-OFF switch and batteries needed

*Each phase has an LED flashing circuit for both the (+) and (-) side of the AC sine wave.

**The is UL Listed self-protected device with 6’ leads. For most installations no fusing is required between the line and the R-3W.**
## ISOLATION VERIFICATION: SAFETY BENEFIT ANALYSIS FOR EXTERNALLY MOUNTED VOLTAGE INDICATORS (VI)\(^{[1]}\)

Analysis of the NFPA 70E Sample\(^{[2]}\) Lock-out Tag-out Procedure ("Live-Dead-Live")

<table>
<thead>
<tr>
<th>NFPA 70E Annex G Reference</th>
<th>Key Concepts</th>
<th>Voltmeter Verification Only (No Voltage Indicator)</th>
<th>Voltage Indicator Safety Benefits(^{[3]}) (in addition to Voltmeter Verification)</th>
<th>Comments &amp; Clarifications Regarding NFPA 70E Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.1</td>
<td>Locate all electrical energy &amp; stored energy sources</td>
<td>Panel Closed Voltmeter not part of the LOTO process until step 6.6</td>
<td>Visible indication of stored &amp; electrical energy with door closed Provides instant critical power system status</td>
<td>For panels with multiple power sources, external VI(s) meet this requirement. Safety procedure needs to have personnel to view/inspect proper indication of the VI.</td>
</tr>
<tr>
<td>6.2</td>
<td>Physically operate the isolator: disconnect power &amp; relieve stored energy</td>
<td></td>
<td>VI(s) warn if any AC or DC energy is still present after operating the isolator</td>
<td>Personnel to visually see the VI stop functioning and/or stored energy slowly dissipate.</td>
</tr>
<tr>
<td>6.3</td>
<td>Apply lockout device Employ additional safety measure (removing a circuit element)</td>
<td></td>
<td>VI still providing information</td>
<td>VI is an “additional safety measure”</td>
</tr>
<tr>
<td>6.4</td>
<td>Attempt to operate the isolator</td>
<td></td>
<td>A VI would indicate an isolator failure, if it “operates” and “reconnects” the power</td>
<td>VI provides immediate feedback to the operator</td>
</tr>
<tr>
<td>6.5</td>
<td>Inspect voltage detecting instrument for damage</td>
<td>Completed in 6.1</td>
<td></td>
<td>Verifying proper operation of VI in step 6.1 is critical to entire safety procedure</td>
</tr>
<tr>
<td>6.6</td>
<td>Verify proper operation of voltage detecting instrument, then test for absence of voltage</td>
<td>If not functioning: needs a battery or repair</td>
<td>Completed in 6.1 The VI provides voltage indication and relative voltage value (^{[3]})</td>
<td>The line voltage is the VI’s only power source (no battery) therefore, if the VI is flashing there must be voltage(s) present inside the enclosure. Flash rate varies with voltage—lower voltage=lower flash rate.</td>
</tr>
<tr>
<td>6.7</td>
<td>Verify proper operation of voltage detecting instrument, after testing for absence of voltage</td>
<td></td>
<td>Completed in 6.2 Disconnect opens and VI ceases to operate</td>
<td></td>
</tr>
<tr>
<td>6.8</td>
<td>Install grounding bars to eliminate induced voltages or stored energy</td>
<td></td>
<td>The <strong>VI is permanently wired</strong> providing ongoing indication if there is stored energy or induced voltages</td>
<td></td>
</tr>
</tbody>
</table>

\(^{[1]}\) For discussion purposes: “power source” is a 3-phase Wye-Delta with Earth Ground and SafeSide® R-3W.


\(^{[3]}\) The traditional “Live-Dead-Live” LOTO safety procedure with a voltmeter remains intact. These comments only describe the added safety benefits if a VI is employed in addition to existing LOTO procedure.
Background:
The purpose of the NEC, as well as the UL 508A Industrial Control Panel Standard, is best summed up in Article 90 of the 2008 NEC:

“90.1 (A) Practical Safeguarding. The purpose of this Code is the practical safeguarding of persons and property from hazards arising from the use of electricity.”

“(B) Adequacy. This Code contains provisions that are considered necessary for safety. Compliance therewith and proper maintenance results in an installation that is essentially free from hazards.”

Compared to the purpose of the NFPA 70E:

“90.1 Purpose. The purpose of this standard is to provide a practical safe working area for employees relative to the hazards arising from the use of electricity.”

“90.2 Scope. (A) Covered. This standard addresses electrical safety requirements for employee workplaces that are necessary for the practical safeguarding of employees during activities such as the installation, operation, maintenance.”

These are two very different goals. While the NEC protects people using electricity and property, the NFPA 70E only protects employees who work with or around electricity. In very few instances these two objectives do not conflict, and when that occurs a hazard risk analysis needs to be performed to determine which solution poses the highest risk. Once this has been determined, we can decide how to resolve this conflict by focusing on reducing the greater risk first. Over-current protection (fusing) of a voltage indicator (VI) provides us with an excellent test case.

Blown Fuse is False Negative:
Getting bit by live voltage is almost always a surprise. Far worse is an electrician starting to work on a conductor that he just tested dead, but actually is live. This is referred to as a false negative indication, which means the voltage detector falsely indicated no voltage. Since the VI’s only full time job is indicating voltage, a blown fuse on its input creates a false negative indication of voltage, which is a hazard. A fuse also adds four connection points of failure for each phase (line-load for fuse and fuse block). In electrical safety, once you touch a live conductor there is ALWAYS an electric incident because electrical energy is instantaneous. Therefore, it is critical to avoid any chance of false-negatives.

Hazard Risk Analysis
Users need to determine the greater risk: The chance of a false negative voltage indication or a damaged or shorted 18AWG wire inside an enclosure?

The Increased Hazard Exception
The NFPA 70E recognizes that perfect safety does not exist and there is always a trade-off between safe and safer. For example, energized work shall be permitted where the employer can demonstrate that de-energizing introduces additional or increased hazards (NFPA 70E 130.1(A)(1)).

The NEC states that a wire without overcurrent protection is a lesser hazard than a non-functioning fire pump motor due to a blown fuse. A greater hazard exists when a building burns down because the fire pump motor doesn’t start due to a blown fuse in he control circuit! “Exception: Overcurrent protection shall be omitted where the opening of the control circuit would create a hazard as, for example, the control circuit of a fire pump motor and the like” NEC 430.72(C)

The informational note in NEC 725.1 provides another example relating to proper installation of Class 1, 2, and 3 remote-control, signaling, and power limited circuits. These circuits have limited power outputs and characteristics that differentiate them from electric light and power circuits, so users may determine “alternative requirements...with regard to...overcurrent protection, insulation requirements, and wiring methods and materials.” In addition, “Remote-control circuits for safety-control equipment shall be classified as Class 1 if the failure of the equipment to operate introduces a direct fire or life hazard [emphasis added]” NEC 725.31(A).

In electrical safety, determining zero electrical energy is critical. Installing overcurrent protection for a VI installation increases the opportunity for a false negative reading thereby potentially creating a greater hazard. Transformers can be excluded from overcurrent protection for reasons specified in NEC 430.72(B), (C)(1) to (5). The construction and design of the VI creates fewer failure points and a higher degree of electrical integrity than transformers.

Continued on page 18
Over-current Protection Design Considerations

Fusing protects both the wires and the devices from permanent damage due to excessive current flow during a short circuit. Since VIs install between all 3-phases and ground, it is imperative that the failure of the VI does not create a bolted fault condition. Consider these design facts relating to fusing the:

High Impedance: SafeSide® VIs are UL Listed as Auxiliary Devices for use in a UL 508A industrial control panels or UL 845 motor control centers. UL performed a single component evaluation test that insures the device would not experience a catastrophic failure due to a component failure, thereby causing a direct short circuit between phases. UL determined that VIs are a self-protected device whereby a single component failure draws no more than 3.7mA current at 750VAC applied to the device. The large passive input resistors on each phase of the VI provides this current limiting function with a nominal current draw of 300μA between phase at 480VAC.

Electrical Integrity: The potted construction adds additional electrical strength to the VI. The physical presence of high voltage only extends ¾” from the rear (inside) where the leads enter the device (Figure 1).

Surge Rated: The VI known as part number R-3W2 carries a CAT III (1000V) and CAT IV (600V) surge rating for reliability.

Integral Lead Wires: The integral potted 18AWG UL listed 1000V rated lead wires will not vibrate loose causing a short circuit to ground. Since the failure mode of the VI is 3.7mA, these wires should not fail due to a device failure.

Wire Protection: An optional NTW conduit adapter (R-3W-DR6) provides physical protection to the wires.

In conclusion, over-current protection will only protect VIs from a damaged lead wire that might short to ground or another bare conductor. If this happens, most likely the current will vaporize the lead wire causing limited damage to the enclosure. Since the lead wire insulation is a flame-rated and UL-listed, it is designed to not sustain a flame. The UL installation sheets also state that overcurrent protection of the leads is not a requirement for every installation.

Other Installations Options: NEC Tap Rule and the UL 508A 12” Rule Approach

NEC 430.72(A), Table 430.72(B) allows smaller conductors to be tapped off larger branch circuits. In addition, the UL 508A 40.3.2 Exception 2 allows for unprotected leads less than 12” from the main disconnect, which gives you two installation options to consider:

- Mount the VI within 12” of the main disconnect. The best location is on the flange or the side of the enclosure. An NPT conduit adaptor (R-3W-NPT125) for the VI may facilitate some other creative mounting options.
- From the main disconnect, wire to terminal blocks as per the NEC tap rule. Locate the terminal blocks within 12” of the VI as per Figure 2.

The NEC has been around a lot longer than the NFPA 70E. The writers of the NEC never envisioned that a safe electrical installation and electrical worker safety would conflict with each other. As shown in this write-up, these inconsistencies are usually mitigated with a little common sense and good logic.

*Products:* VI includes part numbers R-3W, R-3W2, R-3W-SR, and R-3F-Lxx. The same principles described herein apply to the voltage portal installations. Voltage Portals part number scheme included R-1A and R-T3.
VOLTAGE INDICATOR


NOTE:

Short Circuit Current Rating (SSCR) tells the user how much instantaneous short circuit current can pass through a device without permanent damage. Devices that supply current to other devices in normal operation, can have an SCCR rating. SafeSide® VIIs do not have a SCCR rating because they are wired between all three phases and are effectively in a shorted condition when energized. If a short circuit occurs in a system where an VI is installed, the high currents passing through the system will not find a path through the VI and the current flow would not cause any damage to the device. Therefore the SSCR rating is not applicable.

SAFESIDE® VOLTAGE INDICATOR
(part numbers R-3W, R-3W-SR, R-3W2 and R-3F)
Most FAQs below assume a typical 3 phase system

Grounding

Why do I need to connect the green wire to earth ground?
A SafeSide® voltage indicator illuminates whenever there is a voltage differential existing between any two of the four leads. The green GND lead must be connected to a safe ground potential. Because a SafeSide® voltage indicator is a high impedance device, this ground connection can be made to virtually any type of ground (earth ground, signal ground, power ground). The NFPA 70E defines a hazardous voltage as 50 volts or more (referenced to earth ground). Without a solid connection to ground, the voltage indicator will not illuminate on a single phase condition which sets up false-negative voltage reading (voltage exists but is not displayed on the test instrument) and is a very dangerous situation.

What is most important for installation?
Verify and test that the ground connection is solid. Since the GROUND LEDs most likely do not illuminate in a typical balanced 480VAC 3Φ system, it is important to force the GND LED circuit to illuminate by disconnecting one of the phase leads (or pull a fuse).

Will the leakage voltage to ground on a SafeSide® voltage indicator adversely affect my power system?
No. With a typical balanced 480VAC 3Φ system, there is negligible current to ground because the GND LEDs typically do not illuminate. A maximum current of 455μA to ground exists when operating at the 1000 VDC level. If the GND LEDs illuminate during normal operation, there would be anywhere from 100-300 μA leakage current flowing to ground. It takes 60μA to operate the voltage indicator flashing circuit. A leakage current this small would have negligible effect on your power system even with a large number of SafeSide® voltage indicators installed.

Why do the GND LED indicators not illuminate?
This is normal with certain grounding schemes. The GND LEDs typically do not illuminate provided that the 3Φ line voltage on L1, L2 and L3 are balanced and there is no voltage or electrical noise on the GND leg. The GND LEDs will illuminate if an unbalance occurs from a blown fuse, ground fault or single phase condition. Note that it only takes 60μA to illuminate the LEDs in the GND leg.

What about HRG Systems? Isolated Ground Systems?
SafeSide® voltage indicators work on high resistance ground systems. In isolated ground systems, there needs to be a current path through ground to the rest of the circuit or the GND LEDs will not illuminate on a single phase condition. Sometimes isolated ground systems have enough capacitive connection to ground to allow a voltage indicator to function. To be sure a SafeSide® voltage indicator works on your isolated ground system, after wiring the voltage indicator to your 3Φ system, create a single phase condition by pulling two fuses to ensure that a ground connection exists.
Phase Loss and Insensitivity

Are SafeSide® voltage indicators phase sensitive? What if the green lead was accidentally wired to L1, L2, or L3?
No. SafeSide® voltage indicators are phase insensitive. The circuitry behind each of the four leads is identical. If the leads are incorrectly wired, the front phase indication would be incorrect, but the core functionality of the voltage indicator would stay the same. SafeSide® voltage indicators use a high impedance voltage detection circuit per phase to sense and illuminate AC or DC voltage. The illumination of the LEDs occurs only when current passes through two of these voltage detection circuits. Envision four identical voltage detection circuits (L1, L2, L3, GND) meeting each other in the center of the voltage indicator.

Why does the SafeSide® voltage indicator illuminate when the power is off?
The LEDs on the SafeSide® voltage indicator may sometimes illuminate when no voltage is present on its lead wires simply due to induced voltage from other energized conductors. The LED flashing circuit is so sensitive that it only takes 60μA to activate the LED illumination circuit. For example, disconnects fed from a cable tray with other energized conductors may induce enough voltage to illuminate a voltage indicator wired to the line side of that disconnect. Leakage current from power semiconductors is also enough to cause LEDs to illuminate. Please consult factory for additional details.

OSHA and 70E Compliance

Do workers still need to suit up in PPE to open a panel with SafeSide® voltage indicators installed?
It depends. Lock-out/tag-out procedures within a facility need to adhere to the core principles outlined by OSHA and in the NFPA 70E 120. Each facility develops their own procedures specifically to accommodate their unique safety needs. The writers of the NFPA 70E included a process for a hazard risk analysis in ANNEX F to provide the ability for safety managers to discern between safe, safer, and safest when writing their procedures. This question can only be answered once a risk analysis has been completed for the specific installation to determine if a hardwired voltage indicator reduces the risk to an acceptable level, then each facility should make their determination on PPE.

What if the SafeSide® voltage indicator fails?
Creating an electrically safe work condition is a step-by-step process that includes checking the voltage test instrument. NFPA 70E 120.1(5) requires that the “voltage detector is operating satisfactory.” So if a SafeSide® voltage indicator is used as part of the LOTO procedure, then the procedure needs to ensure that the SafeSide® voltage indicator is operating satisfactorily before and after performing the procedure. Personnel must still verify isolation with a meter before performing maintenance. If you chose to use a SafeSide® voltage indicator as part of your safety procedure for lock-out/tag-out, then you must have personnel verify that the SafeSide® voltage indicator is illuminated properly every time the isolator is operated. This is the same procedure an electrician uses to ensure that his meter is functioning.

If the front of the SafeSide® voltage indicators gets sheared off, what is the risk for personnel to be exposed to dangerous voltage?
For part numbers R-3W, R-3W-SR and R-3W2, each of the four input wires enters the rear of the SafeSide® voltage indicator directly into large input resistors which reduce the internal circuit voltage to below 10V. These input resistors reside in the rear of the device and are approximately ¾” long. So the highest voltage in the front of the device is the low voltage LED illumination circuitry. These input resistors also create a highly surge-immune device that can be certified to CAT III/IV to withstand surges up to 6000V.

For part number R-3F, the optical light cable that connects to the LED power source means there is no voltage at the door.
OSHA and 70E Compliance (continued)

**Does OSHA/NEC/NFPA 70E have standards for voltage indicators?**
The informational note found in the NFPA 70E 120.1(5) states that voltage detectors need a UL 61010-01 or equivalent certification. The NFPA 70E is a consensus standard written to serve OSHA’s needs in enforcing electrical safety. Typically OSHA does not approve devices, but may issue letters of interpretation on the application of devices to certain situations.

Electrical devices are installed into a system for a specific electrical function. On the other hand a voltage indicator is installed into an electrical system for a different purpose, namely, electrical safety. Because of this, many of today’s standards have not specifically addressed all the installation opportunities for a voltage indicator.

**Do I still need PPE when opening a panel with a voltage indicator?**
Use of PPE in a given situation requires a hazard risk analysis. See first question under OSHA and 70E Compliance on page 21.

**Will SafeSide® voltage indicators make us NFPA 70E compliant?**
The NFPA 70E is written to explain the principles of an electrical safety program that includes incident energy study, training, and procedures to reach a properly isolated panel. Doing one thing is not considered an electrical safety program. It is the people, the process and the products, coming together to meet the requirements.

**Do I still need to test-before-touch with a voltmeter?**
There are two reasons for doing test-before-touch. 1) A step [NFPA 70E 120.1(5)] in the creation of an electrically safe work condition when using a SafeSide® voltage indicator and 2) the workers personal safety. Testing for the absence of voltage often does not create an electrically safe work condition.

Personal responsibility for your own safety is not a new safety concept, but quite common in occupational tasks that expose people to high fatality and injury rates, like electric shock and arc flash. In these cases, workers always personally perform their own safety checks. Single engine pilots always physically move the plane’s ailerons and check the pitot tube which is the only way the plane gets the required air pressure signal for its instrumentation to function. Once in the air, it is too late to discover that either of these devices don’t work. Similarly, it is too late for a worker who touches a live conductor.

Lastly, since OSHA still requires test-before-touch when working on electrical conductors. A voltage indicator makes this procedure safer by decreasing the probability that workers actually test a potentially ‘live’ conductor.
**General Information**

**What if one LED fails?**
Redundant circuitry provides a second independently operated LED of opposite polarity for each phase, thereby leaving one LED to indicate voltage on that given phase. For DC systems, connecting the (2) leads to the DC+, (1) to DC common, and (1) to ground provides redundancy.

**Do SafeSide® voltage indicators need a test function?**
A SafeSide® voltage indicator, like any voltage detector, needs to be tested to determine if the “voltage detector is operating satisfactory” (NFPA 70E 120.1(5)). A SafeSide® voltage indicator is hardwired and can’t be moved or tested to an independent voltage source. Trying to add a switch to toggle between the line voltage and the test voltage adds more components and complexity, which leads to unreliability. Since the sole purpose of the SafeSide® voltage indicator is to indicate voltage, anything installed between the source voltage and the voltage indicator increases the chance of a false negative voltage reading - switches, relays and fuses included. (Note: A false negative is when voltage exists in a conductor and the voltage detector doesn’t sense it). By installing SafeSide® voltage indicators on all sources, the OSHA required test-before-touch of each circuit part become much safer. A secondary SafeSide® Permanent Electrical Safety Device (PESD) (like our R-T3 voltage portal) is a suitable method of testing the operation of a SafeSide® voltage indicator.

Most safety alerts (i.e. smoke detectors) operate in a normally safe state (houses don’t burn everyday) and require external, yet fallible, power sources (i.e. batteries or 120VAC), and the TEST button typically activates only part of the circuit (the horn). The only true test is creating enough smoke to activate the smoke alarm. Conversely, SafeSide® voltage indicators operate in a normally hazardous state (electrical systems are energized), are powered from the very hazard they indicate (no separate power supply to fail), and their TEST function is seeing it illuminate properly when the isolator is closed. Anything added to the circuit would result in less reliability of the SafeSide® voltage indicator.

**Do I need fuses?**
SafeSide® voltage indicators are unique devices that are not specifically addressed in most of the codes and standard (NEC, NFPA 79, UL 508A). In addition, users typically install SafeSide® voltage indicators as a means of providing safety and not for providing a specific electrical control function. If the primary purpose of installing SafeSide® voltage indicators is for electrical safety, then it should not be fused because that adds additional connections between the voltage indicator and the voltage source, which affects reliability. The NEC allows for unprotected wires when safety is a higher priority. For example, the NEC also allows for fire pump motors to have unprotected control power circuits because it is more important that the fire pump works when there is a fire than for proper protection of control wires. For a more detailed discussion, see Over Current Protection section.

**What are the UL issues and file number for SafeSide® voltage indicators?**
SafeSide® voltage indicators have a C-UL-US Listing (Canada & US). A UL Listing means that there are no “Conditions of Acceptability” (like with a UL Recognized (UR) component). When UL tested these devices they shorted the internal circuitry, and then re-applied voltage without any physical damage due to excessive heat. Therefore, UL concluded that it could be applied without conditions of acceptability and gave these devices a UL Listing (UL with a circle). SafeSide® voltage indicators (R-3W, R-3W-SR and R-3F) are listed in the US and Canada under the UL CCN: NKCR (Auxiliary Device) and was evaluated under the UL 508 specification with file number E256847. The SafeSide® voltage indicator known as part number R-3W2 is UL Listed US and Canada for use in Class 1 Division 2 Environments with file number E334957.