REDUCE RISK WITH PESDs

MAKING NFPA 70E COMPLIANCE SAFER

WRITTEN BY:

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Outline

Abstract - Electrical safety does not mean zero risk, but rather it is a process of decreasing electrical risks and their probability of occurrence to acceptable level. Since the 2000 edition of the NFPA 70E was published, it has fundamentally transformed practices regarding troubleshooting and electrical/mechanical lock-out/tag-out procedures by focusing on ways to lessen electrical risks. Yet, many end-users are choosing to exceed and go beyond the minimum safety standard prescribed in NFPA 70E and they are opting to install Permanent Electrical Safety Devices (PESDs) to curtail risk even further. The byproduct is an electrically *safer* work condition.

An electrically safer work condition is achieved by an automobile manufacturer and Cintas Corporation when they utilize Permanent Electrical Safety Devices (PESDs), which reduce risks and increase the likelihood that zero voltage exists. Permanent Electrical Safety Devices (PESDs) are an example of safety by design. They incorporate electrical safety functionality directly into electrical equipment. While PESDs cannot be used as the sole device to check for the absence of voltage, when partnered with a voltmeter, they create an electrically safer work condition. This allows for workers' exposure to shock and arc flash hazards to be further diminished during LOTO procedures because workers have no susceptibility to voltage.

Warning: Before working on an electrical conductor, verify zero electrical energy with proper voltage testing instrument and the proper procedure as per NFPA 70E 120.1 (5), 120.2 (F)(2)(f)(1-6), OSHA 1910.333(b)(2)(iv)(B).

Index Terms: Permanent Electrical Safety Devices, PESD, NFPA-70E, Voltage detection, Safety Device, Voltage Portal, Test Point Assembly

I. INTRODUCTION

Permanent Electrical Safety Devices (PESDs) are a family of electrical components hardwired to a source of voltages and installed into electrical systems. They enable workers to verify the voltage status of equipment without exposure to the hazard. PESDs reduce the likelihood of arc flash and shock hazard because they diminish voltage exposure, provide voltage labeling on all sources and allow for 24/7/365 visual and/or audible indication of voltage. Figure 1 shows an example of the voltage source labels on a panel fed with three-phase 480VAC and 120V separate control. Proper implementation and selection of PESDs greatly increases the prospect that a worker performing LOTO will have no exposure to voltage, and in some cases, requires no additional personal protection equipment (PPE) beyond the normal 8 cal/cm^2 daily wear. A PESD mounted on the outside of the panel provides workers with the ability to see and check all possible voltage sources [1]. Depending on which PESD is installed on the panel, the combination of visual, audible and physical action required by the worker creates an electrically safer work condition.

Understanding the unique properties, functionality and installation requirements of each kind of PESD is essential to empowering users in the process of selecting the most suitable device for their specific application.

II. TYPES OF PESDs

Figure 1 - Voltage Source Labels

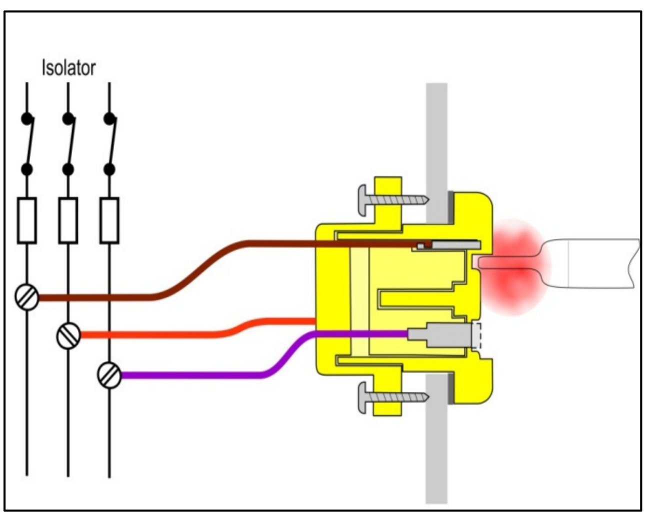

Figure 2 - Cut away of three phase voltage portal

Creating an electrically safer work condition can be achieved with either a single-or three-phase source, which 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 non-contact voltage detector (NCVD) to sense voltages from 50-500/90-1000VAC when placed into an energized voltage portal. The NCVD is a battery operated voltage detector pen that senses AC (but not DC) voltage without actually touching an energized conductor. Figure 2 outlines the fundamental concept of a voltage portal and the associated NCVD.

NCVDs rely on a capacitive coupling to ground, which makes the NCVD less versitile than a phase-phase/phase-ground voltmeter test. However, with voltage portals installed and the panel energized, workers can test the voltage portal with the NCVD to ensure it works. This means a capacitive ground connection exists and will always exist because panels do not move and workers stand in the same place when they test. (Figure 3)[2].

Alternatively, a light emitting diode (LED) type of voltage indicator can be permanently hardwired to the phases and ground. This external device will illuminate when a voltage greater than 20-40VAC/30VDC is applied or when a voltage deferential exists between two lone inputs creating an electrically safer work condition.

The risk reduction characteristics of a three-phase/four-wire voltage indicator include:

- Designed and built solely to indicate the voltage status of a three-phase system.
- Always connected to the source and testing between L1-L2-L3-GRD as per NFPA 70E 120.1(5)
- Powered from the line voltage (no batteries or maintenance)
- Wide operating AC/DC voltage range (20/40-750VAC/30-1000VDC)
- Senses stored energy as per NFPA 120.1(6)
- Meets 50-volt threshold as per NFPA 70E 110.6 (D)(1)(b), 110.7(E)5
- Cat IV surge immunity and UL Certified to UL/ANSI 61010-1 as per NFPA 70E 120.1(5) Informational Note.

Additionally, a zero-energy optical cable voltage indicator as shown in Figure 4 provides the same functionality as per above, but utilizes a non-conductive optical cable for transmitting the LED light. With no voltage to the outside of the electrical enclosure, this system meets the ANSI C37.20.1(7.1.3.7) switchgear specification limiting voltage to the outside of the enclosure to less than 254VAC.

Figure 3 – Voltage portal to NCVD to GRD functionality

Figure 5 shows a three-phase test point device with built-in impedance on each phase, which provides another method of checking voltage with a standard voltmeter without exposing workers to the risk of an arc flash or electrocution. When a LOTO procedure includes both a three-phase test point device and a voltage indicator mounted into panel-mount housing**,** it increases the likelihood that the workers' voltmeter test will yield only a zero voltage reading. The built-in impedance of 56K ohms on L1, L2, and L3 affects voltage readings by approximately 10% when using a typical digital voltmeter, however this is not applicable at the zero voltage range. Yet, the benefit of this approach is it limits the current outside of the enclosure to approximately 10mA. This reduces the propensity of a worker inadvertently causing a short circuit while performing a voltmeter test, which could result in an arc flash. The 10mA current threshold is below 17-99mA range that could cause death [3]. In addition, depending on the installation and local codes, limiting the current to 10mA may eliminate the need for short circuit protection of a test point device.

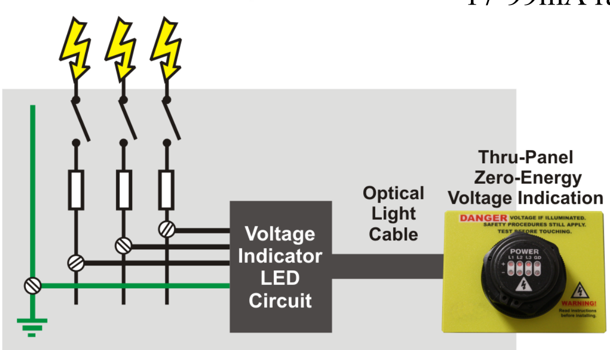

Figure 4 - Zero Energy Voltage Indicator System

A test point assembly with no impedance is a variation on this same concept with its own unique advantages and disadvantages. Without built-in impedance, the energy to the outside of the panel is limited only by the fuses and lead-

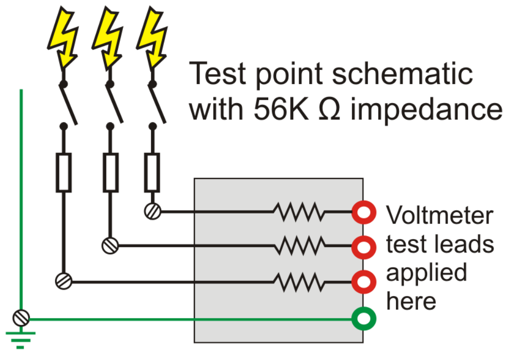

Fig. 5 Test Point with Energy Limiting Impedance

wires to the test points. On the other hand, these test points provide a more direct connection to the source, which is an advantage. This is yet another example of creating an electrically safer work condition.

III. PESDs INSTALLATION REDUCES RISKS

Because PESDs hardwire to the primary source disconnect and install on the exterior of the electrical equipment, they require an environmental type rating identical to the enclosure on which they are affixed and a minimum 600-volt component rating. When PESDs are installed on the enclosure flange in close proximity to the main disconnect, the installation eliminates the hazard of having 480 volt conductors on the door. The close proximity of a PESD to the main disconnect also reduces the lead wire length and minimizes potential electrical interference with other components inside the enclosure. Providing short circuit protection on PESDs is another choice users must make between electrical safety and electrical integrity of their installation. Short circuit protection means that 12 additional connections - or failure points - are added between the source voltage and the PESD as per Figure 6. These failure points increase the likelihood of a false negative voltage indication. In most cases, the only risk is the failure of the PESD lead-wires, not the PESD [4]. In addition, manufacturers of electrical equipment are providing more reliable termination points for PESDs on their equipment. Article 430.72 of the National Electrical Code also allows for the omission of short circuit protection if opening of a circuit would create a hazard. One last minor point; some facilities decide to fuse PESDs because they believe workers should use them as a presence-of-voltage indication, while others believe PESDs should be used for absence-of-voltage. In the latter case, PESDs should be installed without fuses.

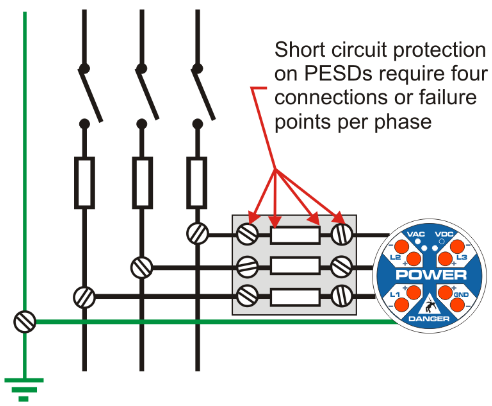

Figure 6 - Potential failure point when fusing a PESD

IV. EXAMPLES OF PESDs REDUCING RISKS

A large automobile manufacturer had concern over the level of PPE and the presence of voltage on the line side of their switchgear. This concern encouraged a common practice of requiring workers first to locate then isolate the correct upstream source disconnect when necessary. Figure 7 shows a

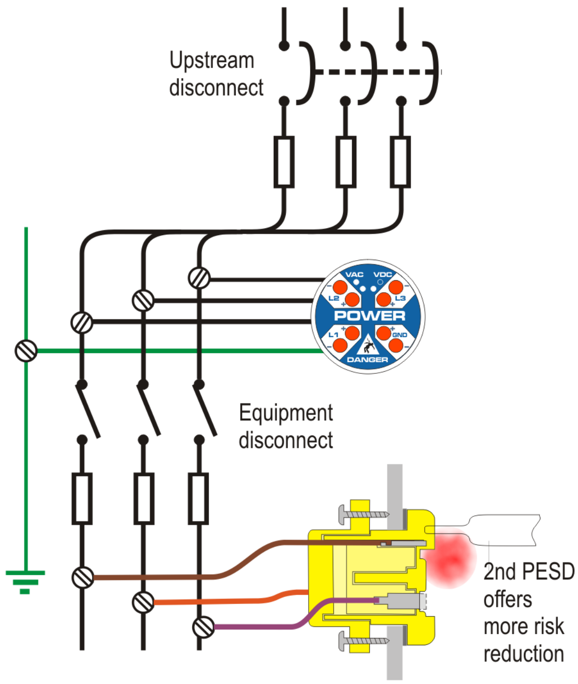

Figure 7 - PESDs on the line and load side of equipment disconnect.

PESD installed on the line side of the equipment disconnect reduces risks in two ways. First, it provides an indication that the proper upstream source has been disconnected. Second, it statistically increases the likelihood that a zero electrical energy state exists inside the equipment electrical panel. Without a PESD, the worker must assume that voltage exists both on the line and load side of the equipment disconnect unless proven otherwise. In order to prove this without a PESD, the worker dons PPE and performs a voltmeter test on the conductors in question. Alternatively, with a voltage indicator installed, the worker verifies its proper operation and then witnesses a change-of-state immediately after opening the upstream disconnect. It is important to note that the worker is not exposed to voltage during this process.

The next step is to open the equipment disconnect. With the upstream source isolated and the equipment disconnect opened, the change-of-state on the voltage indicator (illuminated to non-illuminated) ensures a high probability for zero voltage to exists inside the equipment enclosure. It would require three device failures in close succession for voltage to be present, so a worker verifying with a voltmeter will likely show zero volts. Using a risk assessment procedure, the automobile manufacturer would conclude that there is a reduction in risk under this scenario that may allow workers to enter an equipment enclosure and verify zero electrical energy with a voltmeter while utilizing a reduction in PPE.

In a similar example, Cintas Corporation installed PESDs to protect its employees and to increase productivity in their automated plants. In these types of plants, Cintas' laundry equipment resides behind a restricted safety fence. Cintas' procedures require that all the equipment within the restricted area be put into a safe state whenever a worker enters this area. After Cintas evaluated their maintenance-related downtime, they determined their electrical maintenance procedures disproportionality affected their productivity-especially in the automated plants. It took workers a significant amount of time to retrieve and suit up in PPE each time a maintenance task required access to the inside of an electrical panel. Once workers established zero energy inside the panel, they would remove their PPE to comfortably perform the maintenance task, which also added to the downtime.

Fig. 8 Test Point Voltage Indicator Assembly and Housing with Clear Cover

Cintas used a two-part PESD assembly that included a voltage indicator and fused hard-wired test points (no built-in impedance) in a clear-cover housing as shown in Figure 8. With the power on and the panel door closed, the worker has a visual indication that voltage exists and a test point to confirm the voltage indicator is functioning properly. Once the isolator is opened, the worker witnesses the voltage indicator change-of-state from illuminating to non-illuminating; this provides the first indication that the power has been disconnected, which reduces the likelihood that the test points have voltage. The test points are specifically designed to accept standard voltmeter probes, and the clear cover prevents inadvertent access to voltage by a non-qualified employee. Next, the worker uses the live-dead-live procedure with a voltmeter to verify zero voltage exists between L1, L2, L3 and GRD as per the procedure below and NFPA 70E 120.1(5). Like the automobile manufacturer example, a failure of the isolator, the test points with the meter, and the voltage indicator need to occur in close succession for voltage to exist inside the panel. Using this process, which includes the steps in NFPA 70E 120.1(1-6), is not only more efficient, but creates an electrically safer work condition. This process is inherently safer because it eliminates the likelihood for maintenance employees to test potentially live conductors inside an electrical enclosure using a voltmeter. The process is at the same more time efficient because maintenance employees do not have to take additional time to gather, don and remove electrical PPE. The far reaching result of this approach is the ability to achieve safety improvements along with productivity increases that benefit both Cintas and their employees.

When a facility has properly maintained electrical equipment installed with available short circuit current ratings and interrupting times that do not exceed the maximum as described in NFPA 70E Table 130.7(C)(15)(a), they can use those tables for determining the PPE required for performing each specific task. In this case, smaller companies with a less skilled electrical maintenance staff can also benefit from PESDs. 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 worker performing mechanical LOTO in some facilities would be required to work in tandem with an electrician using a voltmeter to physically verify zero voltage inside an electrical panel before work begins. In that case, the electrician is exposed to voltage. With PESDs, the mechanic can single-handedly check for zero electrical energy without any exposure to voltage, which makes the LOTO procedure safer and more productive.

V. SUMMARIZING THE RISK REDUCTION PROPERTIES OF EACH PESD

Every time workers create an electrically safe work condition as per NFPA 70E 120.1, they subject themselves to multiple hazards. The risk exposure directly correlates with the procedures and devices used in their LOTO program. Each of the devices used – from a voltmeter to the varied PESDs - have their own unique risk characteristics that are both good and bad. Table 1 lists each risk characteristic compared to a voltmeter and assigns a rating that allows users to graphically see the risk factors for each type of PESD[5]. The goal is ensuring a worker's voltmeter measures zero voltage once he accesses the inside of the enclosure.

For example, "testing duration" is the first risk characteristic listed in Table 1. The voltage indicator is colored green for reduced risk because this device is hardwired to the source and constantly tests all three phases and ground simultaneously all the time. On the other hand a voltmeter is colored yellow for moderate risk because a worker with a voltmeter performs one test at a time by touching each conductor with the voltmeter leads and testing between each phase and ground. Therefore, the "test duration" is a risk characteristic of a voltage indicator that increases the safety of a LOTO procedure as compared to a voltmeter.

In the second row of Table 1, the risk characteristic "ability to test other circuit parts" gives the voltage indicator a red rating because it is hardwired to a single set of conductors and cannot test other circuit parts within the enclosure. In this example, the voltmeter is assigned a moderate risk because it can test other circuit parts but the worker may be exposed to voltage.

Since PESDs are inexpensive, many times users choose selected combinations of PESDs to further reduce their risks. Table 1 also provides the ability for users to see and select the right PESD combinations, not only to meet the requirements of their electrical safety program, but also to accommodate different installation and environmental issues. For instance, a user would select a voltage portal over a test point assembly in a harsh environment because test jacks will eventually fail due to the corrosive atmosphere and a voltage portal would not.

VI. WRITTEN LOTO PROCEDURES AND MECHANICAL LOTO

A PESD becomes a safety device only after it is included as part of a written LOTO procedure. Without being included in written LOTO procedures, 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. The automobile manufacturer and Cintas Corporation applications would not have been possible without the addition of PESDs into their LOTO procedures.

VII. CONCLUSION

The end-goal when utilizing PESDs is to create a safer work condition by reducing risks and increasing the likelihood that the zero energy exists inside the panel when a worker enters to test for voltage with his meter. Permanent Electrical Safety Devices (PESDs) are an example of safety by design and they incorporate functionality directly into electrical equipment. This allows for the workers' exposure to shock and arc flash hazards to be further diminished during LOTO procedures because workers have no susceptibility to voltage.

The applications of PESDs are an example of how safety and economics benefit each other. Under NFPA 70E 120.1(1-6), creating an electrically safe work condition is done solely with a voltmeter, but by adding PESDs into this process a *safer* work condition is created.

VIII. REFERENCES

[1] NFPA 70E, 2012 *Standard for Electrical Safety in the Workplace* 120.1(1)

[2] Duane Smith, "What Do You Know About Capacitive Voltage Sensors?" Electrical Construction and Maintenance, Aug. 1, 2005, (http://ecmweb.com/content/what-do-you-know-about-capacitive-voltage-sensors)

[3] From OSHA.gov website: https://www.osha.gov/SLTC/etools/construction/electrical_incidents/eleccurrent.html

[4] http://www.graceport.com/assets/files/Data%20Sheets/SafeSide_OvercurrentProtection_2013(1).pdf

[5] Red=inherent risk; Yellow=moderate risk; Green=reduced risk

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

TABLE 1 – PESD RISK ASSESMENT CHART

Risk Assesment	Voltage Indicator	Optical Cable Voltage Indicator	Test Point Assembly in housing	Test Point Assembly (impedance limited) in housing	Voltage Portal	Voltmeter	Notes and Clarifications:
Testing duration	24/7/365*		Touch Test				*Hardwired and teststing all phases and ground all the time exceeding NFPA 70E 120.1 (1-6).
Test to zero voltage* and other circuit parts -OSHA 1910.333(b)(2)(iv)(B)	NO		NO		NO	YES	*Some voltage indicators have a votlage threshold down to 20VAC/DC
Shock hazard	NO		YES	NO (Note 3)	NO	YES	
Arc flash hazard	NO		YES	NO*	NO	YES	*Impedence limited test jack assembly eliminates arch flash hazard.
Enclosure rating suitability	NO		Corroding test jacks*		NO	N/A	*Harsh environments can corrode test jacks making them unsuitable for a reliable test.
Line voltage on enclosure exterior	YES	NO	YES		YES	N/A	
Fusing required (Note 2)	NO	NO	YES		NO	N/A	
Best mounting location	Flange*	Flange/Door	Flange*		Flange*	N/A	*Enclsoure mounted devices on the door or other is a risk.
Method of validation	Voltage indicator cannot be verified to a separate source* Independent device (voltage portal or test jack)*		Test voltmeter to another source voltage		Test NCVD to voltage portal and another source voltage	Another source voltage	*OSHA 1910.333(b)(2)(iv)(B) does not require testing voltmeter to a known souce, like NFPA 70E 120.1(5)does. *Secondary PESD to validate its proper operation.
Connection to source	Hardwired				Capacitively coupled*	Test Leads**	*Moderate risk: worker stands in the same location can verify ground path. **Test leads make temporary connections
Connection to ground	Hardwired						
Indentfies (labels) voltage sources	YES					NO	All sources hardwired to PESDs effectively identifies all sources as per NFPA 70E 120.1.
Sutiable for mechanical LOTO (Note 4)	YES					YES*	*With no PESD, voltage exposure is assumed for worker.

Risk Reduced	Green
Moderate Risk	Yellow
Inherent Risk	Red

Notes:

Note 1: Some voltage indicator designs have as much as 2mA ground leakage current that increases as more voltage indicators are installed.

Note 2: Fuses add additional connections and failure points that increase the likelihood for a false negative voltage reading (voltage exists and not indicated on test instrument). See: http://www.graceport.com/assets/files/Data%20Sheets/SafeSide_OvercurrentProtection_2013(2).pdf

Note 3: The likelihood that voltage exists after opening the isolator and/or used in conjunction with a voltage indicator is very low.

Note 4: Mechanical LOTO has a lower burden of proof for electrical energy isolation.

TABLE 2 - PESD CHARACTERISTIC COMPARISON TABLE

Characteristics	Voltage Indicator	Optical Cable Voltage Indicator	Test Point Assembly (impedance limited in housing)	Voltage Portal	Voltmeter
Test Instrument Requirement	Part of the Device		Typical Industrial Multimeter	Non-Contact Voltage Detector (NCVD)	Typical Industrial Multimeter
Voltage Range	20-750VAC/30-1000VDC design specific		600V	0-1000VAC (50/90-1000VAC)	1000V (Typical)
Number of Phases	3 Phase & Ground		2 Phases tested at a time	3 Phase with no Ground	2 Test leads
UL 61010-01 certification	CAT III/IV		CAT III/IV	Cat III/IV	Cat III/IV
Voltage Indication	Visual		Digital Readout	Visual and Audible	Digital
Batteries Required	NO		YES	Portal-NO, NCVD-YES	YES
Enclosure UL Rating	Type 12/13/4/4X		Type 12/13/4/4X with housing door closed	Type 12/13/4/4X	N/A
Ground leakage current (Note 1)	<60µA to 1-2mA depending on circuit		None	None	N/A