Electrical Safety Innovation

How today's technology is enabling the next-generation of electrical LOTO

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Agenda

1. Review Prevention through Design, Hierarchy of Controls, Electrical Hazards
2. Electrical LOTO Example
3. Voltage Testing Technologies
4. Best practices for evaluating and applying electrical safety technology

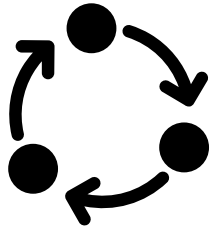
Prevention through Design, Hierarchy of Controls & Electrical Hazards

Prevention through Design (PtD)

The practice of anticipating and designing out hazards as early as possible in the lifecycle of a product

Applies **throughout** organization

Think **new** & **existing** equipment



Consider entire **lifecycle**

Hierarchy of Risk Controls

Most Effective

Elimination — Physically **remove** the hazard

Substitution — **Replace** the hazard

Engineering Controls — **Isolate** people from the hazard

Administrative Controls — **Change** the way people work

PPE — Protect the worker with **Personal Protective Equipment**

Least Effective

PtD Focus

Lockout Tagout (LOTO)

Control of Hazardous Energy
OSHA 29 CFR 1910.147

- Chemical
- Electrical
- Hydraulic
- Mechanical
- Pneumatic
- Thermal

Electrical Hazards

Shock

Arc flash

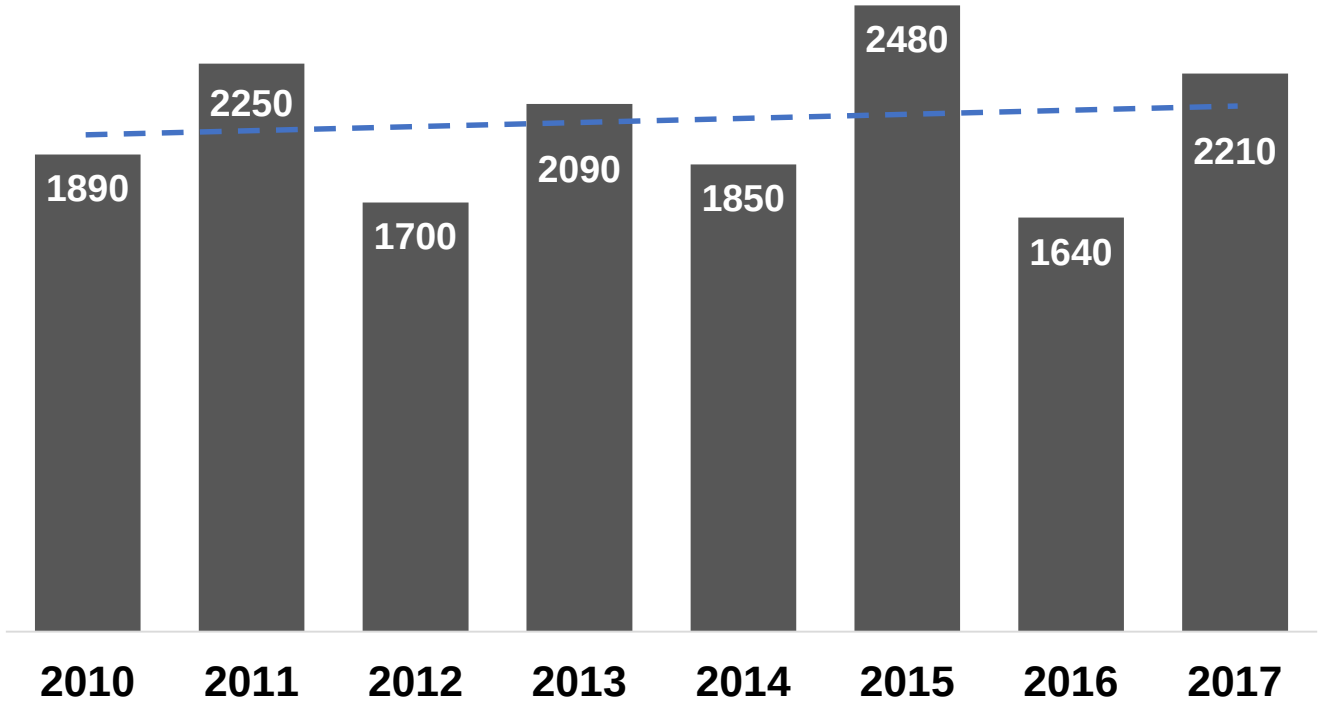
Fire

Electrical hazards impact everyone – not just electrical workers!

Time for Innovation

The number of electrical injuries is **no longer decreasing**

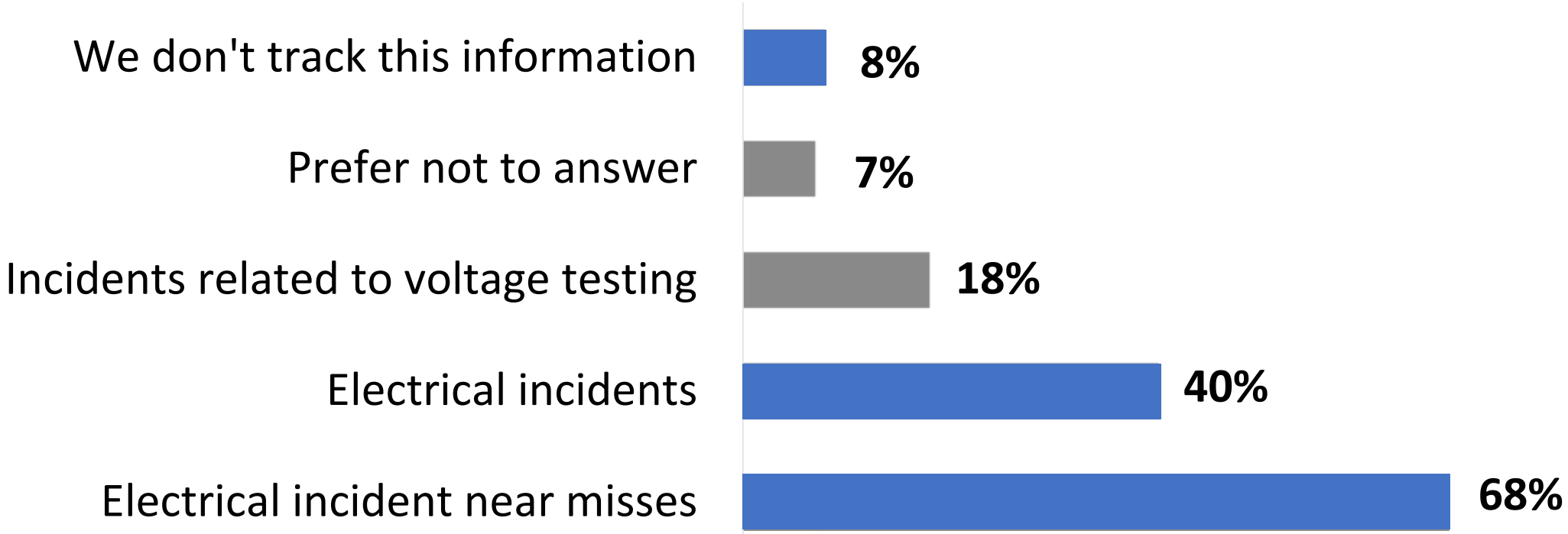
Many believe electrical injuries are **underreported**



Source: http://files.esfi.org/file/Workplace-Electrical-Injuries-2003-2017-F927.pdf

Frequency of Electrical Incidents

Question: Have you experienced any of the following within the past five years?



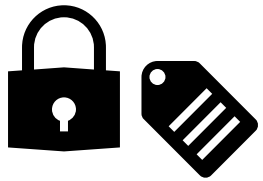
Source: EHS Today – 2019 Survey

Example:
Electrical Lockout/Tagout

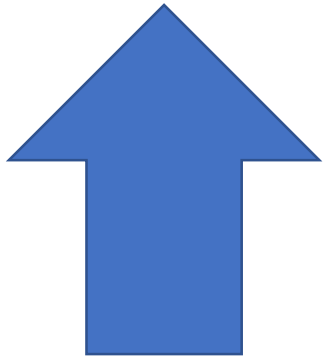
LOTO…and then **Verify**!

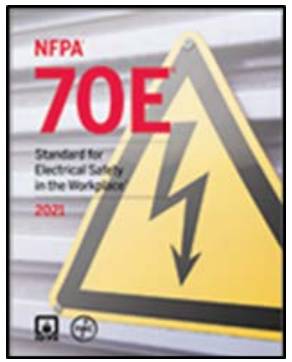
Isolate

Apply Locks/Tags



Verify





Verifying a De-Energized Condition

NFPA 70E **120.5 Process for Establishing and Verifying an Electrically Safe Work Condition**

(7) Use an adequately rated portable test instrument to test each phase conductor or circuit part to verify it is de-energized. Test each phase conductor or circuit part both phase-to-phase and phase-to-ground. Before and after each test, determine that the test instrument is operating satisfactorily through verification on any known voltage source.

Portable Testers Have Limitations

Error Setting Function Selection Switch
Electrician severely burned when a multimeter switch **was incorrectly placed in resistance mode** prior to making contact with terminals in a 480V MCC.[1]

Inadequately Rated Tester
Arc created when a voltmeter was connected across two phases of a bus bar. Arc caused tester to overload and explode resulting in one fatality and another worker with serious burn injuries.[2]

Error Reading Digital Display
"OL" or over-range was misinterpreted to mean "zero" or no voltage present, resulting in a near-miss.[1]

Use of Improper Portable Tester
Although a **non-contact voltage probe** did not indicate voltage, a lighting circuit was in fact energized, resulting in electrical shock.[3]

Using a Voltmeter for verification has limitations…

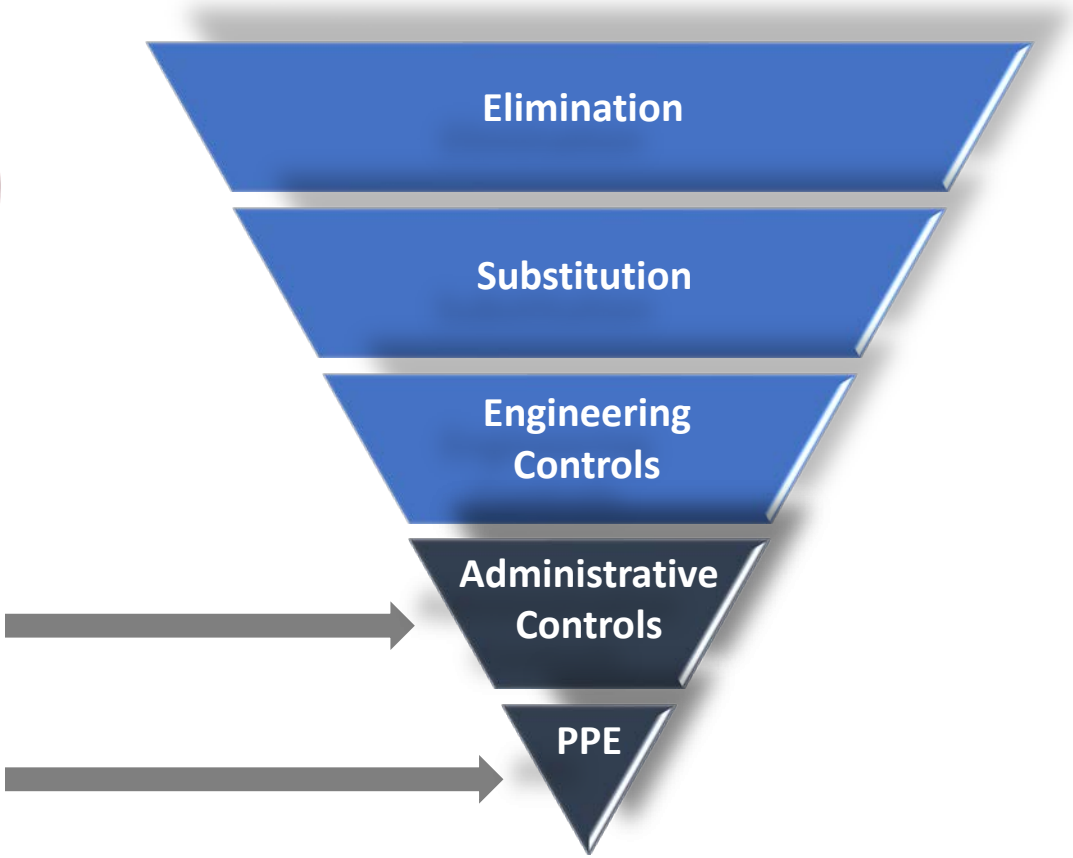
- Hardware failures
- Human error
- Process failures
- Misinterpretation
- Exposure to hazards

[1] H. L. Floyd and B. J. Nenninger, "Personnel safety and plant reliability considerations in the selection and use of voltage test instruments," IEEE Trans. Ind. Appl., vol. 33, no. 2, pp. 367–373, 1997.
[2] "Hispanic factory worker dies of burns after improperly testing a 480-volt electrical bus bar," Fatality Assessment and Control Evaluation (FACE) Program, Nat. Inst. Occupational Safety Health, Centers Disease Control Prevention, U.S. Dept. Health Human Services, Cincinnati, OH, 2005.
[3] J. Prigmore, J. Bishop and J. Martens, "Electrical Investigations: Case Studies, Common Electrical Safety Mistakes, and Lessons Learned," *IEEE Electrical Safety Workshop, 2018*.

LOTO and Verification

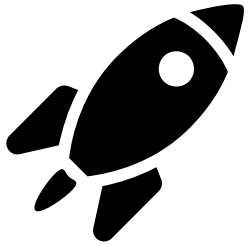
<u>Traditional process</u> relies on:

- Portable testers
- Procedures
- Training
- Personal protective equipment

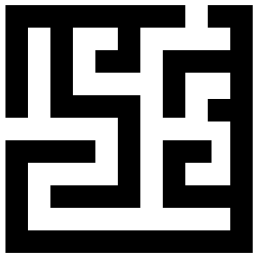


Administrative Controls

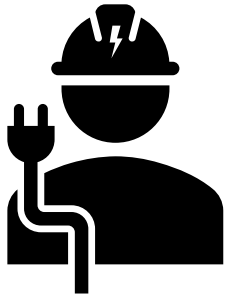
Effective when **performed as prescribed**



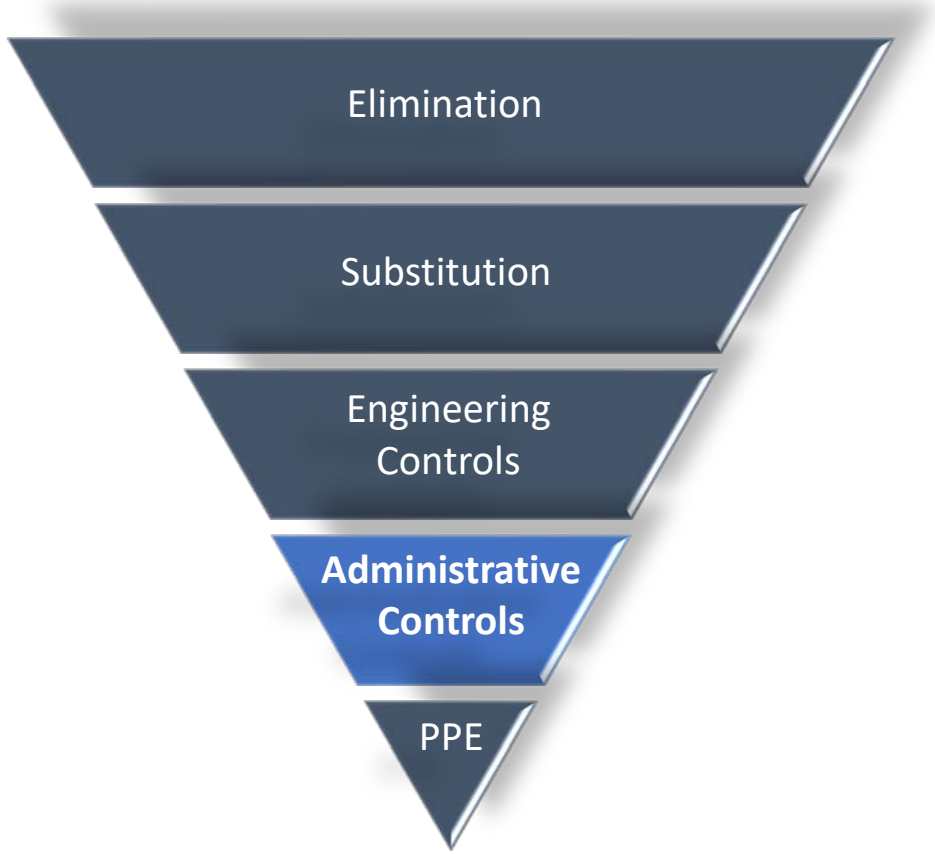
Normalization of deviance



Complexity leads to **shortcuts**



Experience does **not mean fewer errors**



Human Factors

In a study of **electrical burn** patients, researchers found that **no patient** in the study **followed all appropriate safety measures.**

Source: J. Nobel, M. Gomez, and J.S. Fish, “Quality of Life and Return to Work Following Electrical Burns,” *Burns*, vol. 32, 20. 2, p. 159-164, 2006.

Could design features help ensure **each step** of the process is completed?

Can design options make voltage testing more **efficient**?

Can **exposures** be reduced?

Applying Prevention through Design

Use of an **installed** tester

☑Reduces **likelihood** of exposure and **severity** of exposure

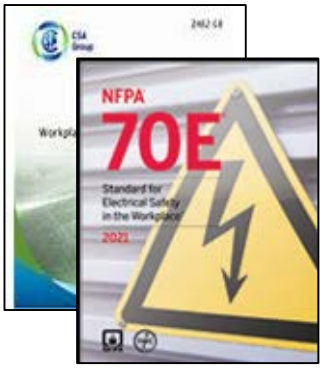
☑Reduces **errors** from inadequately rated testers

Automating the test process

☑Improves **consistency** of the verification process

☑Reduces **human errors**

☑Improves **efficiency**



Verifying a De-Energized Condition

NFPA 70E-2021 120.5 Process for Establishing and Verifying an Electrically Safe Work Condition

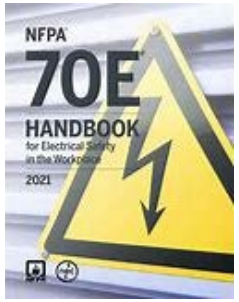
CSA Z462-2021 4.2.5 g) Exception 2) & Note 1

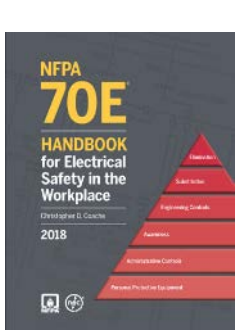
(7) Use an adequately rated portable test instrument to test each phase conductor or circuit part to test for the absence of voltage. Test each phase conductor or circuit part both phase-to-phase and phase-to-ground. Before and after each test, determine that the test instrument is operating satisfactorily through verification on any known voltage source.

Exception No. 1 to (7): An adequately rated permanently mounted absence of voltage tester shall be permitted to be used to test for the absence of voltage of the conductors or circuit parts at the work location, provided it meets the all following requirements:

1) It is permanently mounted and installed in accordance with the manufacturer's instructions and tests the conductors and circuit parts at the point of work
2) It is listed and labeled for the purpose of verifying the absence of voltage
3) It tests each phase conductor or circuit part both phase-to-phase and phase-to-ground
4) The test device is verified as operating satisfactorily on any known voltage source before and after testing for the absence of voltage

Informational Note No. 2. For additional information on rating and design requirements for permanently mounted absence of voltage testers, refer to UL 1436, Outlet Circuit Testers and Other Similar Indicating Devices.





NFPA 70E Handbook,
2018 & 2021 Edition

120.5(7) Article 120

Exception No. 1: An adequately rated permanently mounted test device shall be permitted to be used to verify the absence of voltage of the conductors or circuit parts at the work location, provided it meets the all following requirements: (1) It is permanently mounted and installed in accordance with the manufacturer's instructions and tests the conductors and circuit parts at the point of work; (2) It is listed and labeled for the purpose of verifying the absence of voltage; (3) It tests each phase conductor or circuit part both phase-to-phase and phase-to-ground; (4) The test device is verified as operating satisfactorily on any known voltage source before and after verifying the absence of voltage.

Typically measurement devices indicate when voltage is present, but lack of indicating a voltage does not guarantee the equipment has been de-energized. For this reason, these mounted devices are designed to run internal diagnostics, verify operation on a known voltage source, confirm contact with the circuit, and verify the lack of voltage. These measurement devices do not use equipment voltage to verify the operation of the device. A secondary test source is available to perform this function. The device will then actively indicate the lack of voltage. See Exhibit 120.14 for an installed absence of voltage tester indicating that equipment is de-energized. Absence of voltage testing equipment for fixed installations is listed to UL 1436, *Standard for Outlet Circuit Testers and Similar Indicating Devices*.

Establishing an Electrically Safe Work Condition

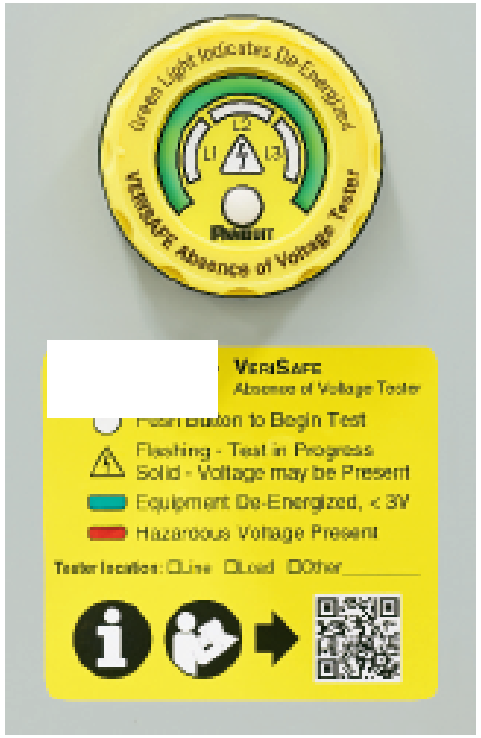


EXHIBIT 120.14

Absence of voltage tester. (Courtesy of Panduit Corp.)

Comparison of Test Methods

Portable Testers

Select Tester → Open Panel → Test Tester → Check for Voltage → Retest Tester → Perform Work

Manual Process
Possible Exposure to Electrical Hazards
On average takes **10-20 minutes** to complete

vs.

Absence of Voltage Testers

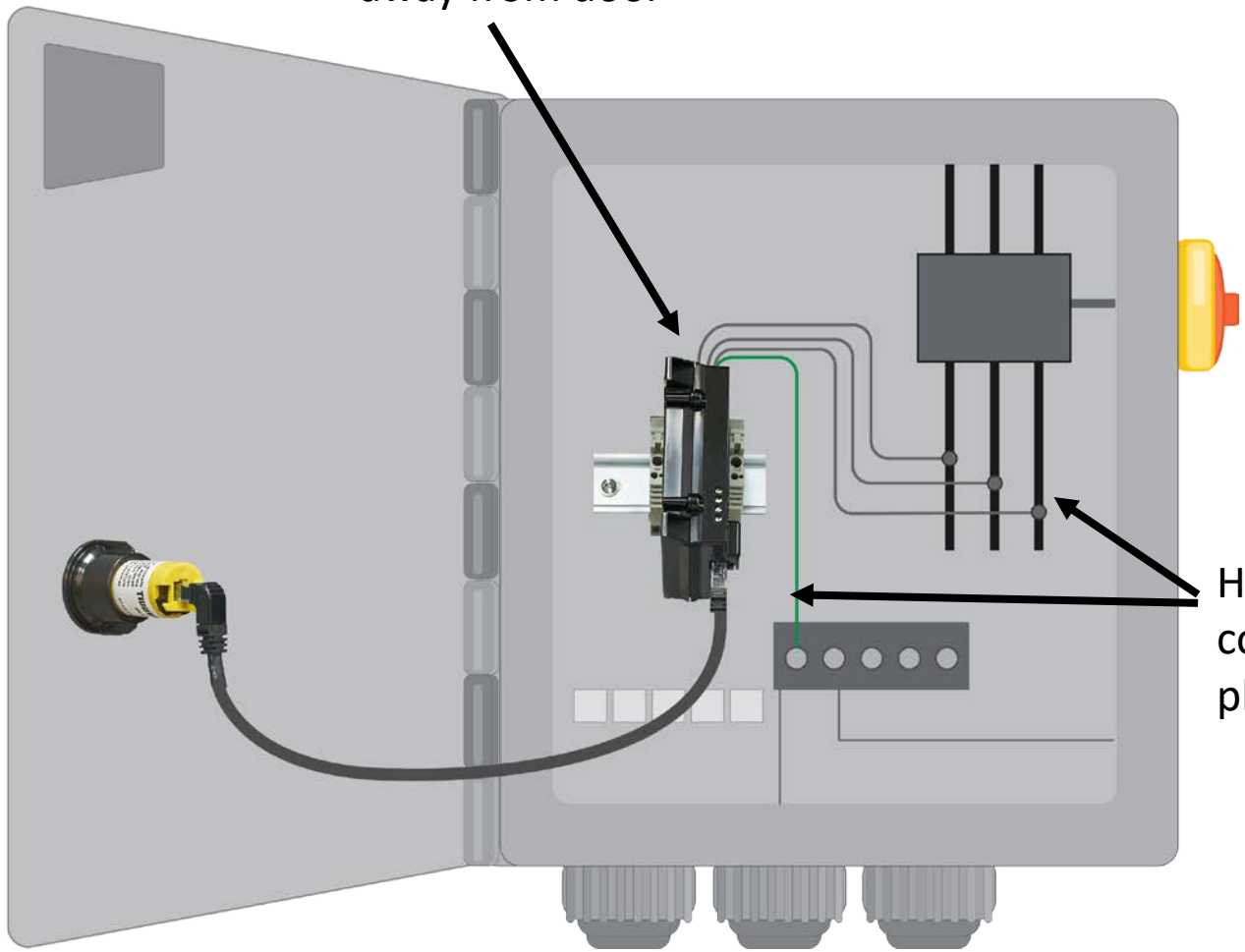
Activate the VeriSafe™ Absence of Voltage Tester → Open Panel → Perform Work

Test the Tester → Verify Installation → Check for Voltage → Re-Verify Installation → Re-test the Tester → Indicate Result

Automatically Performed in Sequence
No Exposure to Electrical Hazards
Takes **less than 10 seconds** to complete

Permanently-Mounted Absence of Voltage Tester

Test before doors are open



Keep hazardous voltage away from door

Hardwired connections to each phase and ground

Traditional Method with **Portable Tester**

Using a **Permanently-Mounted Absence of Voltage Tester** (AVT)

VeriSafe™ Absence of Voltage Tester

Combines **Voltage Presence** Indication with **Absence of Voltage Testing**

Red LEDs indicate **hazardous voltage present**

Upstream Power: ON

Lack of red LEDs **does not guarantee** voltage absence

Upstream Power: OFF

Push to initiate test and see progress

Upstream Power: OFF

Green indicates **absence of voltage** is confirmed

Upstream Power: OFF

UL 1436

AVT Listing & Labeling Requirements

Key AVT Requirements

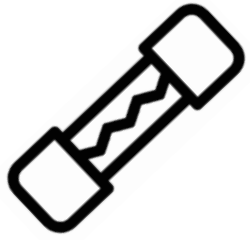
UL 1436 Standard for Outlet Circuit Testers and Similar Indicating Devices, 6th Edition (September 6, 2016)
https://standardscatalog.ul.com/standards/en/standard_1436

User initiated test

Installation test &
"test the tester"

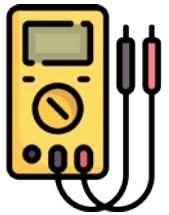
Test for **AC and DC voltage**

Active indication

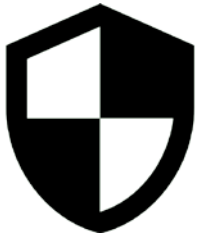


Internal **overcurrent protection**

Keep Hazardous voltage off the door



Electrical requirements in **UL 61010**



Functional safety requirements

Electrical Construction

- IEC 61010 Provides general safety requirements for electrical and test measurement equipment
  - Protection from electrical shock
  - Electrical spacing and insulation requirements
  - Impulse and transients
  - Mechanical impact
  - Environmental hazards

- Electrical construction requirements are based on combination of Overvoltage Category and Working Voltage
  - CAT IV 1000V – 12 kV impulse
  - CAT IV 600V – 8 kV impulse
  - CAT IV 300V – 6 kV impulse
  - CAT III 1000V – 8 kV impulse
  - CAT III 600V – 6 kV impulse
  - CAT III 300V – 4 kV impulse

Functional Safety and VeriSafe AVTs

- Any part of the AVT **safety function** must meet **SIL 3 requirements**
- The VeriSafe AVT exceeds SIL 3
  - Hazardous failure rate (λDU) of 10
  - Probability Failure per Hour (PFH) of 10^{-8}

10^{-8} equates to **1 failure** per:

100 million operating hours

11,000+ years

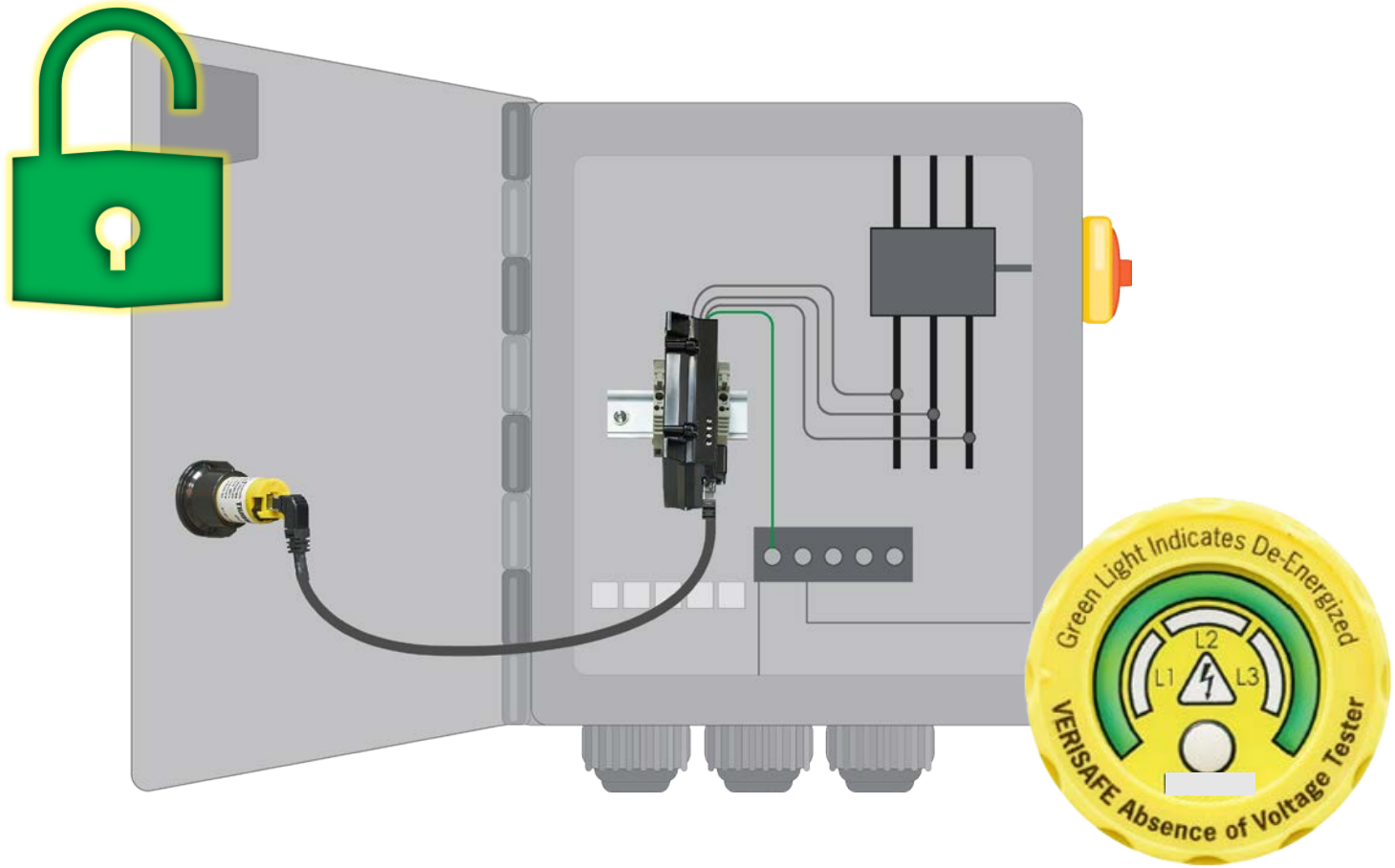
36 billion tests

Use Cases

Access Control

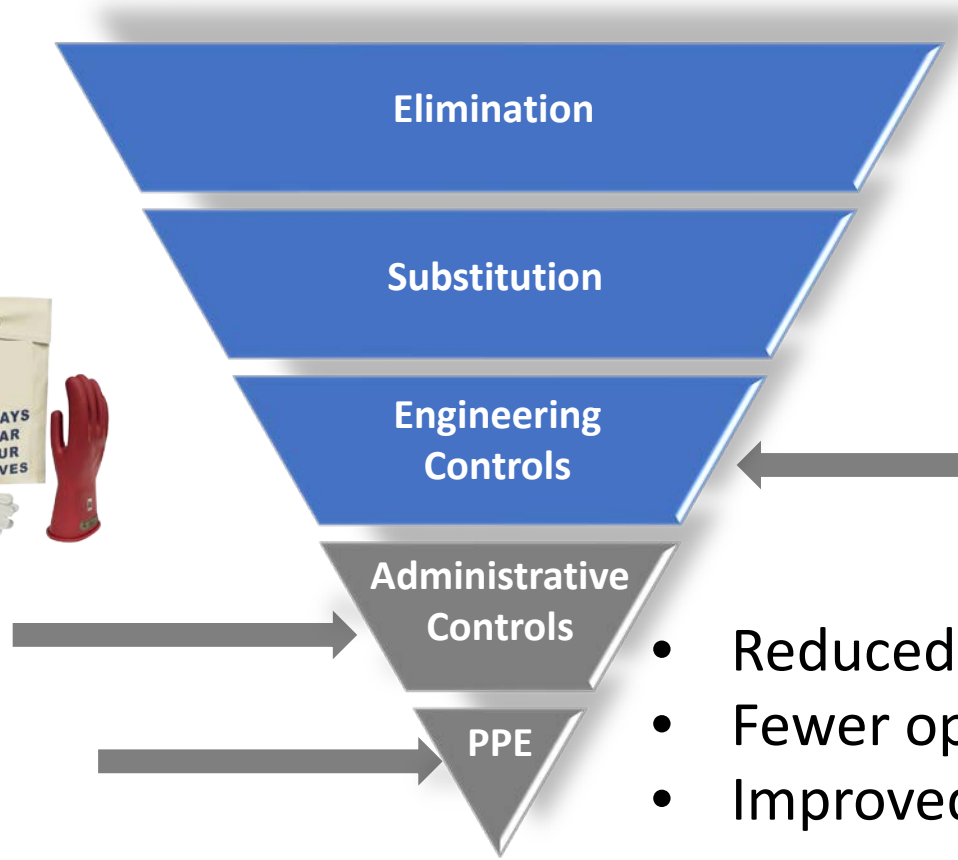
Reduce workplace hazards through design

Provides an **added layer of protection**



Next-Generation of Electrical LOTO

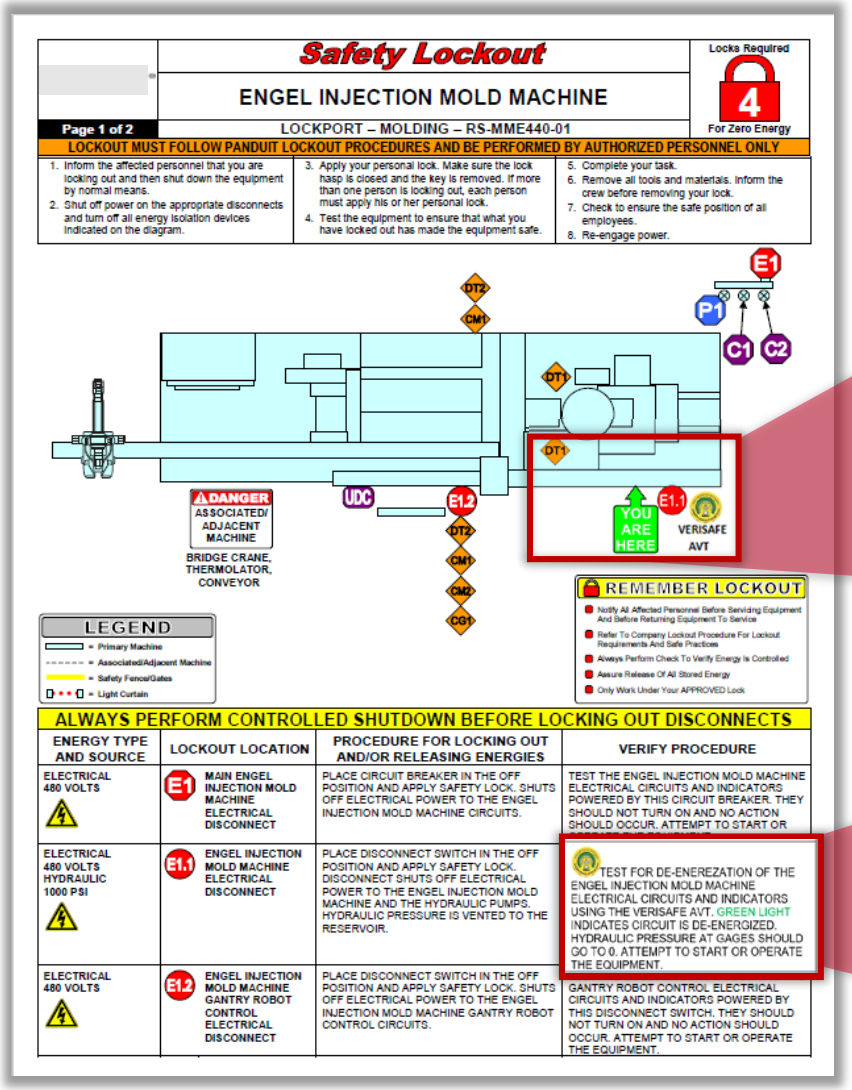
Traditional Process



Automated System

- Reduced **exposure** to hazards
- Fewer opportunities for **human error**
- Improved **efficiency**

Absence of Voltage Testers & Lockout/Tagout



Safety Lockout

ENGEL INJECTION MOLD MACHINE

Page 1 of 2

LOCKPORT – MOLDING – RS-MME440-01

Locks Required 4 For Zero Energy

LOCKOUT MUST FOLLOW PANDUIT LOCKOUT PROCEDURES AND BE PERFORMED BY AUTHORIZED PERSONNEL ONLY

1. Inform the affected personnel that you are locking out and then shut down the equipment by normal means.
2. Shut off power on the appropriate disconnects and turn off all energy isolation devices indicated on the diagram.
3. Apply your personal lock. Make sure the lock hasp is closed and the key is removed. If more than one person is locking out, each person must apply his or her personal lock.
4. Test the equipment to ensure that what you have locked out has made the equipment safe.
5. Complete your task.
6. Remove all tools and materials. Inform the crew before removing your lock.
7. Check to ensure the safe position of all employees.
8. Re-engage power.

DANGER ASSOCIATED/ ADJACENT MACHINE

BRIDGE CRANE, THERMOLATOR, CONVEYOR

YOU ARE HERE

VERISAFE AVT

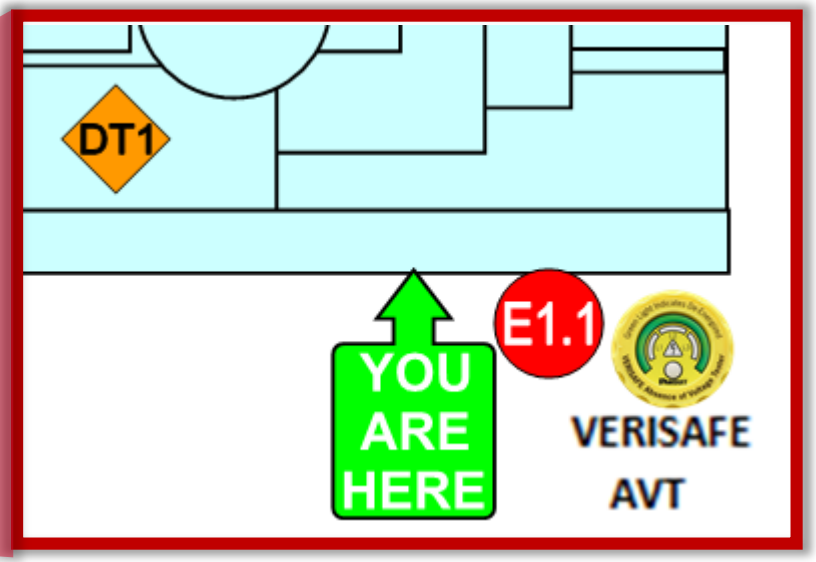
LEGEND

REMEMBER LOCKOUT

- Notify All Affected Personnel Before Servicing Equipment And Before Returning Equipment To Service
- Refer To Company Lockout Procedure For Lockout Requirements And Safe Practices
- Always Perform Check To Verify Energy Is Controlled
- Assure Release Of All Stored Energy
- Only Work Under Your APPROVED Lock

ALWAYS PERFORM CONTROLLED SHUTDOWN BEFORE LOCKING OUT DISCONNECTS

ENERGY TYPE AND SOURCE	LOCKOUT LOCATION	PROCEDURE FOR LOCKING OUT AND/OR RELEASING ENERGIES	VERIFY PROCEDURE
ELECTRICAL 480 VOLTS	E1 MAIN ENGEL INJECTION MOLD MACHINE ELECTRICAL DISCONNECT	PLACE CIRCUIT BREAKER IN THE OFF POSITION AND APPLY SAFETY LOCK. SHUTS OFF ELECTRICAL POWER TO THE ENGEL INJECTION MOLD MACHINE CIRCUITS.	TEST THE ENGEL INJECTION MOLD MACHINE ELECTRICAL CIRCUITS AND INDICATORS POWERED BY THIS CIRCUIT BREAKER. THEY SHOULD NOT TURN ON AND NO ACTION SHOULD OCCUR. ATTEMPT TO START OR
ELECTRICAL 480 VOLTS HYDRAULIC 1000 PSI	E1.1 ENGEL INJECTION MOLD MACHINE ELECTRICAL DISCONNECT	PLACE DISCONNECT SWITCH IN THE OFF POSITION AND APPLY SAFETY LOCK. DISCONNECT SHUTS OFF ELECTRICAL POWER TO THE ENGEL INJECTION MOLD MACHINE AND THE HYDRAULIC PUMPS. HYDRAULIC PRESSURE IS VENTED TO THE RESERVOIR.	TEST FOR DE-ENEREZATION OF THE ENGEL INJECTION MOLD MACHINE ELECTRICAL CIRCUITS AND INDICATORS USING THE VERISAFE AVT. GREEN LIGHT INDICATES CIRCUIT IS DE-ENERGIZED. HYDRAULIC PRESSURE AT GAGES SHOULD GO TO 0. ATTEMPT TO START OR OPERATE THE EQUIPMENT.
ELECTRICAL 480 VOLTS	E1.2 ENGEL INJECTION MOLD MACHINE GANTRY ROBOT CONTROL ELECTRICAL DISCONNECT	PLACE DISCONNECT SWITCH IN THE OFF POSITION AND APPLY SAFETY LOCK. SHUTS OFF ELECTRICAL POWER TO THE ENGEL INJECTION MOLD MACHINE GANTRY ROBOT CONTROL CIRCUITS.	GANTRY ROBOT CONTROL ELECTRICAL CIRCUITS AND INDICATORS POWERED BY THIS DISCONNECT SWITCH. THEY SHOULD NOT TURN ON AND NO ACTION SHOULD OCCUR. ATTEMPT TO START OR OPERATE THE EQUIPMENT.



Test for de-energization of the Engel injection mold machine using the VeriSafe AVT. Green light indicates circuit is de-energized. Hydraulic pressure at Gages should go to 0. Attempt to start or operate the equipment.

Equipment with AVTs

Control Panels, Motor Control Centers, Safety Switches, Switchgear, Switchboards, Transformers, Packaged Drives, Bus Duct, etc.

AVTs are solutions for
- ✓ New equipment
- ✓ Retrofits
- ✓ OEM installations

CONTROL PANEL

MOTOR CONTROL CENTER (MCC)

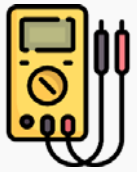
SWITCHBOARD

Comparing Voltage Testing Technologies

“But I Trust My Portable Tester…”

	Typical Portable Tester	VeriSafe AVT
I can see what I’m testing	Exposure to hazards, conductors may not be exposed	Connectivity is part of every test
Functionality Test	Live-Dead-Live	Automatic Live-Dead-Live with Built-in Known Voltage Source
Voltage Rating	Varies	Up to 600V
Overvoltage CAT	CAT III / IV	CAT III (600) / CAT IV (300)
UL Listing	UL 61010 or IEC 61243-3	UL 61010, UL 1436, UL 508
Functional Safety		SIL 3
Third-party certification	✓	

Portable Testers Have Risk



Inadequate ratings

Exposure to Hazards

Human Error

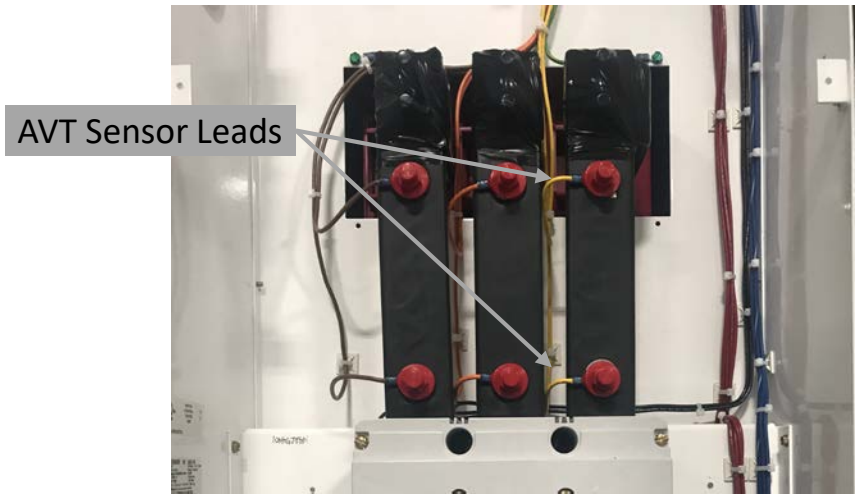
Misinterpretation of Settings or Readings

Damaged or **improperly installed** probes

Access to a known voltage source

Lack of contact with conductors or ground

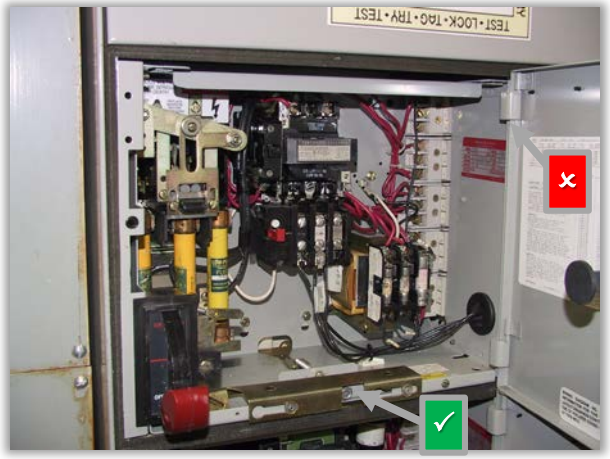
Voltage Testing Traps



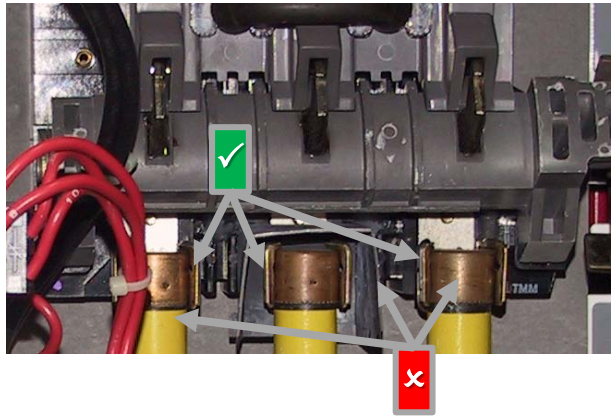
Insulated Conductors

Barriers

Obstructed Access/Poor Visibility



Finding a Reliable Ground



Fuses & Accessories

Terminology Matters

Portable Test Instruments

Digital Multimeter	Voltage Detector	Voltage Presence Indicator / Voltage Detector
UL/IEC 61010	IEC 61243-3	UL 1436 / UL/IEC 61010

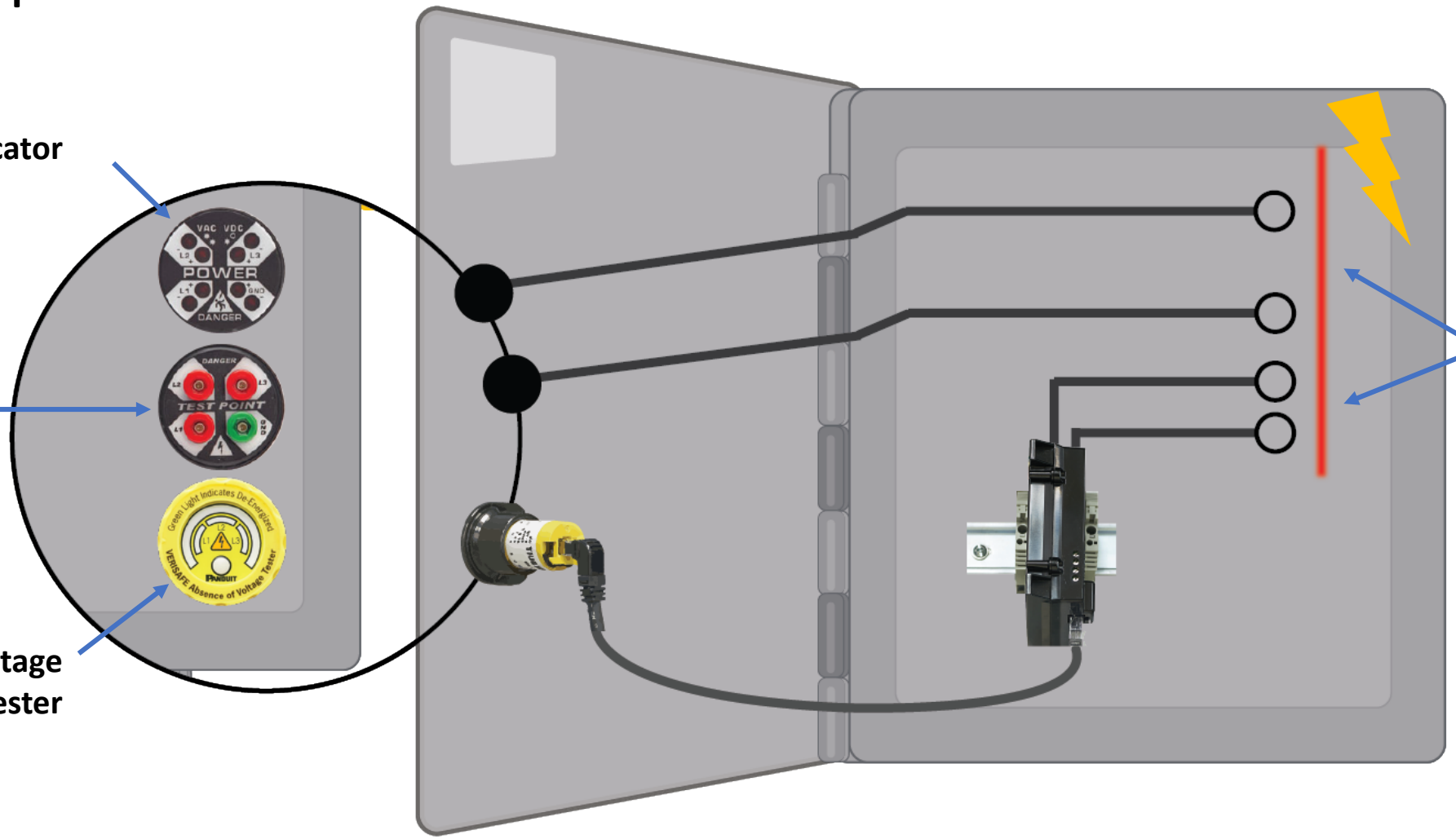


Permanently Mounted Products

Absence of Voltage Tester (AVT)	Voltage Indicator	Voltage Portals	Analog or Digital Panel Meter
UL 1436 / IEC/UL 61010	UL/IEC 61010	UL/IEC 61010	IEC/UL 61010



Importance of the Installation Test



Best Practices
evaluating and applying electrical safety technology

Future Vision

A connected infrastructure…designed for **safety**.

Summary

- To advance electrical safety, embrace the continuous improvement mindset
  - Leverage the near miss
- Use Prevention through Design when mitigating hazards
  - Control measures that are designed in are more effective than administrative controls and PPE alone
- Seek out new technology and innovation
  - New solutions to old problems like LOTO and verification are now viable

How can you apply
PREVENTION THROUGH DESIGN
at your organization?