



Electrical Safe Work Practices, Test Instruments and Associated Requirements.

Jim Dollard

NFPA 70E

Flintlock Technical Services



1

Objectives

- Test Instrument Types
- Requirements for Test Instruments
- NFPA 70E requirements
- Ratings & Design
- Use
- Training



2022 NECA SAFETY PROFESSIONALS CONFERENCE



2

Requirements for Test Instruments

- General Requirements
- Test Instrument Use
- Ratings and Design
- Operation Verification
- Non-contact (Voltage Detection)
- Types of Test Instruments
- Permanently mounted absence of voltage testers
- Training
- Policies

2022 NECA SAFETY PROFESSIONALS CONFERENCE



3

Incidents and Test Instruments

- The use of test instruments typically places the worker in close proximity to exposed energized conductors and circuit parts
- There is human interaction and an increase in the likelihood of arc flash
- Human error always plays a role
- Equipment design
- Complacency
- Type of test instrument
- Inside RAB

2022 NECA SAFETY PROFESSIONALS CONFERENCE



4

Human Interaction

DONNIE'S ACCIDENT

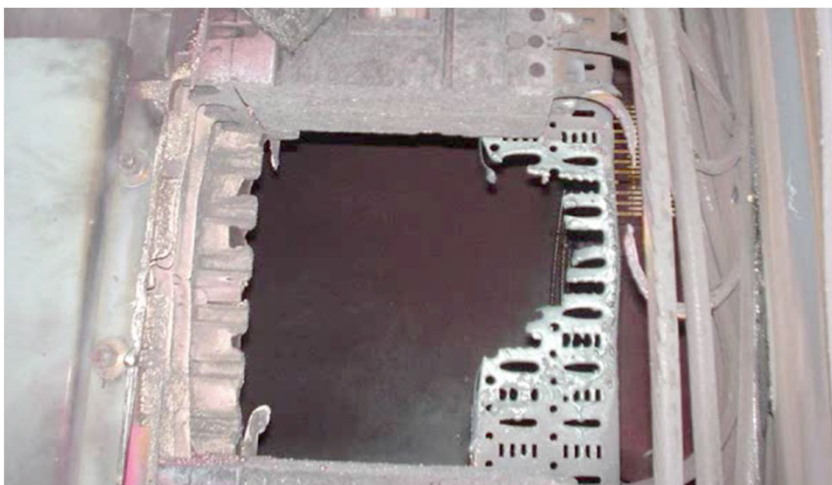


Caution: Several of the following images are very graphic.

2022 NECA SAFETY PROFESSIONALS CONFERENCE

5

Human Interaction



2022 NECA SAFETY PROFESSIONALS CONFERENCE

6

Human Interaction



2022 NECA SAFETY PROFESSIONALS CONFERENCE



7

Human Interaction



2022 NECA SAFETY PROFESSIONALS CONFERENCE



8

Human Interaction



2022 NECA SAFETY PROFESSIONALS CONFERENCE



9

Human Interaction



2022 NECA SAFETY PROFESSIONALS CONFERENCE



10

Incidents and Test Instruments

- NFPA 70E defines an arc flash hazard in Article 100
 - A source of possible injury or damage to health associated with the release of energy caused by an electric arc
- Technically correct
 - When/where does an arc flash hazard exist?
- IN No. 1... when energized electrical conductors or circuit parts are exposed..... provided a person is interacting with the equipment in such a manner that could cause an electric arc

2022 NECA SAFETY PROFESSIONALS CONFERENCE



11

Incidents and Test Instruments

- The use of test instruments is typically performed on exposed electrical conductors or circuit parts
- The use of test instruments is interacting with the equipment in such a manner that could cause an electric arc



2022 NECA SAFETY PROFESSIONALS CONFERENCE



12

Safe Use of Test Instruments

- Test Instruments are used by electrical workers when performing diagnostics, testing, start up, & troubleshooting
- Test Instruments are used to test for the absence of voltage when an ESWC is created
- Product standards for test instruments have changed significantly as design contributed to incidents
- NFPA 70E requirements for test instruments, have changed significantly to provide safer working conditions

2022 NECA SAFETY PROFESSIONALS CONFERENCE



13

Test Instruments Design

- Product standards for test Instruments have evolved resulting in safer design and use
- For example, older style digital multimeters and other test instruments that used metal banana plugs
- These banana plugs were easily pulled out of the test instrument



2022 NECA SAFETY PROFESSIONALS CONFERENCE



14



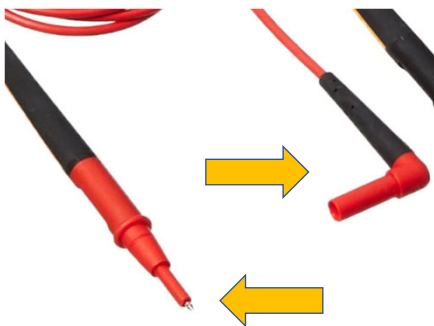
2022 NECA SAFETY PROFESSIONALS CONFERENCE



15

Test Instruments Design

- Older style metal banana plugs exposed and longer metal probes making contact



2022 NECA SAFETY PROFESSIONALS CONFERENCE



16

NECA Guide on Test Instruments

- Focuses on *test instruments* used by electrical workers and requirements for the safe use and application of these devices as addressed in NFPA 70E
- Additional detailed information is available in the:
 - *NECA Guide to Decision Making*
 - *NECA Guide Energized vs. Deenergized Work*
 - *NECA Guide to Shock and Arc Flash Risk Assessments*
 - *NECA Guide to NFPA 70E Employer (Contractor) Responsibilities*
 - *NECA NFPA 70E Personal Protective Equipment (PPE) Selector Guide*
 - *NECA NFPA 70E Lockout/Tagout Guide*
 - *NECA Guide to NFPA 70E Policies and Best Practices.*

2022 NECA SAFETY PROFESSIONALS CONFERENCE



17

Test Instruments

- There are many different types of test instruments and test equipment used by electrical workers
- NFPA 70E does not identify all the different types of test instruments and equipment
- NFPA 70E requirements apply to all test instruments
 - voltage, current and phase rotation
- NFPA 70E does not use the term “voltage detector”
 - Referenced only in an IN

2022 NECA SAFETY PROFESSIONALS CONFERENCE



18

Test Instruments

- NFPA 70E permits only qualified persons to use test instruments for tasks such as testing, troubleshooting, and voltage measuring on electrical equipment where an electrical hazard exists
- 110.8(A)..... where an electrical hazard exists
- A dangerous condition such that contact or equipment failure can result in electric shock, arc flash burn, thermal burn, or arc blast injury
- Plugging a vacuum cleaner.... electrical hazard?

2022 NECA SAFETY PROFESSIONALS CONFERENCE



19

Test Instruments

- NFPA 70E permits only qualified persons to use test instruments for tasks such as testing, troubleshooting, and voltage measuring on electrical equipment where an electrical hazard exists



2022 NECA SAFETY PROFESSIONALS CONFERENCE



20

Test Instrument Training

- NFPA 70E requires that all qualified persons be trained to select an appropriate test instrument for the task to be performed
- The employee must demonstrate how to use the specific device to test for the absence of voltage, including interpreting indications provided by the device
- An extremely important part of this required training is to ensure that the employee understands all limitations of each test instrument that might be used

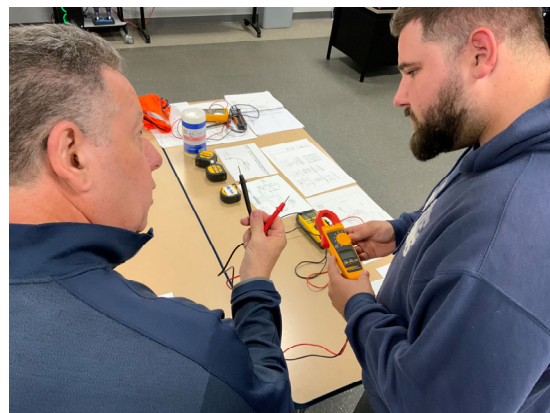
2022 NECA SAFETY PROFESSIONALS CONFERENCE



21

Test Instrument Training

- Demonstrate how to use the specific device to test for the absence of voltage
- Interpreting indications provided by the device
- Understands all limitations of each test instrument that might be used



2022 NECA SAFETY PROFESSIONALS CONFERENCE



22

Test Instrument Training

- Trained to:
- (1) select an appropriate test instrument for the task,
- (2) demonstrate the use of a specific device to test for the absence of voltage,
- (3) interpret indications provided by the device and,
- (4) understand all limitations of each test instrument that might be used

2022 NECA SAFETY PROFESSIONALS CONFERENCE



23

Test Instrument Training

- (1) select an **appropriate test instrument for the task**,
- (2) demonstrate the use of a specific device to **test for the absence of voltage**,
- (3) **interpret indications** provided by the device and,
- (4) understand all **limitations** of each test instrument that might be used



2022 NECA SAFETY PROFESSIONALS CONFERENCE



24

Rating and Design

- Test instruments, associated equipment, and all accessories must be rated for the circuits and equipment on which they will be used
- Ratings include but are not limited to: voltage, current and overvoltage category ratings.
- This guide is focused primarily on utilization voltages and test instruments with ratings of typically 600 volts and 1000 volts

2022 NECA SAFETY PROFESSIONALS CONFERENCE



25

Rating and Design

- Unqualified persons, not properly trained make mistakes
- 600 test equipment rapidly disassembles when used on circuits and equipment rated over 100 volts
- Overvoltage ratings, based upon the potential overvoltage the test instrument may be exposed to within an electrical distribution system
- These categories are: CAT I, CAT II, CAT III and CAT IV.

2022 NECA SAFETY PROFESSIONALS CONFERENCE



26

Rating and Design

- Voltage spikes can be generated by motors, capacitors, variable speed drives, power conversion equipment and lightning on outdoor transmission and distribution conductors
- These transients can reach peak values high enough to destroy a test instrument with the potential to severely injure the employee
- A higher category (CAT #) number addresses the use of test instruments on energized conductors and circuit parts where higher values of available fault current and higher values of transient energy are known to exist

2022 NECA SAFETY PROFESSIONALS CONFERENCE



27

Rating and Design

- Test instruments rated at 1000 volts will provide superior protection to one rated at 600 volts
- For example, a test instrument rated CAT III at 1000 volts will provide superior protection over a test instrument rated at CAT III 600 volts



2022 NECA SAFETY PROFESSIONALS CONFERENCE



28

Overvoltage Ratings	
CAT I	Protected electronic equipment
CAT II	Single-phase receptacle connected loads such as appliances and portable tools
CAT III	3-phase distribution including single-phase commercial lighting and equipment in fixed locations such as switchgear and polyphase motors
CAT IV	3-phase at the utility connection, outdoor conductors, electricity meters, and service entrances

29

Inspection and Repair of Test Instruments

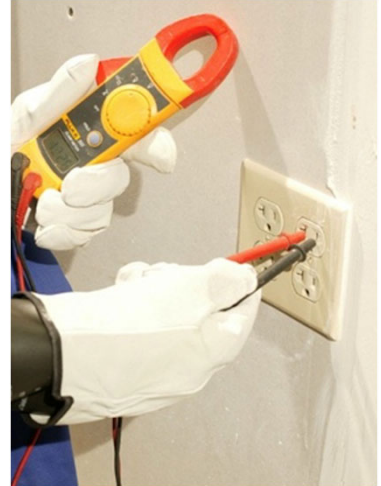
- Employees must be trained to visually inspect test instruments and equipment and all associated test leads, cables, power cords, probes, and connectors for external defects and damage before each use
- Defective or damaged equipment must be removed from service
- All repairs must be performed by a person(s) qualified to perform the repairs
- Tests are necessary to ensure that the equipment operating and is safe to use



30

Operation Verification

- Testing for the absence of voltage is a critical step in the creation of an ESWC
- Qualified persons must demonstrate the use of the test instrument for absence of voltage testing
- It is important to understand that the creation of an ESWC includes energized work
- When an employee removes covers and uses a contact test instrument to test for the absence of voltage, they are performing energized work



2022 NECA SAFETY PROFESSIONALS CONFERENCE



31

Operation Verification

- NFPA 70E requires the operation of the test instrument be verified on any known voltage source before and after an absence of voltage test is performed
- The test instrument does not need to be verified at the same voltage of the equipment being placed into an ESWC
- For example, when testing for the absence of voltage in a panelboard rated at 480/277 volts, verification of operation could be performed by testing for voltage in a female cord cap on an extension cord at 120 volts

2022 NECA SAFETY PROFESSIONALS CONFERENCE



32

Operation Verification

- 120.5 provides prescriptive direction on how to test for the absence of voltage in the process provided for establishing and verifying an ESWC
- An adequately rated portable test instrument must be used to test each phase conductor or circuit part for the absence of voltage
- Prescriptive steps are provided and before and after each test the qualified person must determine that the test instrument is operating satisfactorily through verification on any known voltage source



2022 NECA SAFETY PROFESSIONALS CONFERENCE

33

Operation Verification

- Non-contact test devices are not permitted to be used for testing for the absence of voltage
 - See 120.5(7) Exception No. 2 to (7) for systems over 1000 volts, noncontact capacitive test instruments are permitted
- Absence of voltage testing on electrical systems over 1000 volts, is permitted to be performed with a noncontact capacitive test instrument to test each phase conductor
- NFPA 70E permits permanently mounted absence of voltage testers
 - See 120.5(7) Exception No. 1 to (7), for systems over 1000 volts, noncontact capacitive test instruments are permitted

2022 NECA SAFETY PROFESSIONALS CONFERENCE

34

120.5(7)

- *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 all of the 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 testing for 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.*
- *Exception No. 2 to 7: On electrical systems over 1000 volts, noncontact capacitive test instruments shall be permitted to be used to test each phase conductor.*

2022 NECA SAFETY PROFESSIONALS CONFERENCE



35

Non-contact (Voltage Detection)

- Non-contact test devices very simply detect the presence of voltage
- These devices have gained popularity in the electrical construction industry as they are easily carried in a pocket or clipped to a shirt
- May be used as an indication of the presence of voltage but are not permitted when testing for the absence of voltage



2022 NECA SAFETY PROFESSIONALS CONFERENCE



36

Non-contact (Voltage Detection)

- Non-contact voltage testing devices work by sensing a very small amount of current that is capacitively coupled from the live circuit to the tester and back to ground
- By holding the tool, the employee is the ground reference through a capacitive coupling
- If an employee is not grounded, such as when wearing an insulating glove or standing on a non-conductive ladder, the ground reference through capacitive coupling is gone and the test device may not indicate the presence of voltage

2022 NECA SAFETY PROFESSIONALS CONFERENCE



37

Non-contact (Voltage Detection)

- Will not detect voltage in conductors that are shielded
- Other limitations exist with cable types such as Type NM cable
- The paper wrap inside of this plastic jacketed cable assembly can absorb moisture in damp areas
- This moisture is in direct contact with an uninsulated equipment grounding conductor resulting in a shield over the energized conductors within



2022 NECA SAFETY PROFESSIONALS CONFERENCE



38

Non-contact (Voltage Detection)

- While a non-contact test device will provide an indication of voltage in dry Type NM cable, where it is damp, such as temporary wiring, the test device may not provide an indication of the voltage present
- Non-contact test devices may be useful as an indicator but may never be used to test for the absence of voltage.
- See the new IN following 130.7(C)(1)
 - Risk reduction methods

2022 NECA SAFETY PROFESSIONALS CONFERENCE

39

Types of Test Instruments

- NFPA 70E contains general requirements for all test instruments but does not identify them by the type of device
- The *most common* use of test instruments for electrical workers is testing for the absence of voltage and troubleshooting
- The most common types of test instruments used for these tasks include but are not limited to *solenoid-based voltage testers* and *electronic voltage testers* (similar in size and shape to a solenoid-based voltage tester) with *digital multimeters* used in some cases.



2022 NECA SAFETY PROFESSIONALS CONFERENCE

40

Types of Test Instruments

- Training must be on the specific test instrument:
 - must include how to test for the absence of voltage,
 - how to interpret indications provided by the device and,
 - most importantly an understanding of the limitations of each test instrument that might be used

2022 NECA SAFETY PROFESSIONALS CONFERENCE



41

Solenoid Type Test Instruments

- Solenoid based voltage testers are very popular
- An electromagnetic coil moves a ferrite core against a spring and are commonly used up to 480 volts
- These devices are momentary contact type testers and cannot be held in place on an energized circuit
- Limitations on the lower voltage range. In many cases these devices will not get enough current flow to move the ferrite core below 100 volts



2022 NECA SAFETY PROFESSIONALS CONFERENCE



42

Electronic (voltage testers) Test Instruments

- Electronic voltage testers are similar in size, shape and design to a solenoid-based voltage tester
- Typically capable of measuring voltage from 12 to 600 volts
- Much higher input impedance limiting the amount of current flow through the device which can result in a false positive (ghost voltage) created through induction from an energized conductor



2022 NECA SAFETY PROFESSIONALS CONFERENCE

43

Digital Type Test Instruments

- Digital multimeters are commonly used
- Testing for the absence of voltage and troubleshooting
- They are used to measure voltage, current, and resistance
- These devices are a diagnostic tool for used by electricians, technicians and others in electrical/electronic industries
- These devices can measure precise values of voltage typically from millivolts through 1000 volts ac.

2022 NECA SAFETY PROFESSIONALS CONFERENCE

44

Digital Type Test Instruments

- Digital multimeters are commonly used
- Testing for the absence of voltage and troubleshooting
- They are used to measure voltage, current, and resistance
- These devices are a diagnostic tool for used by electricians, technicians and others in electrical/electronic industries
- These devices can measure precise values of voltage typically from millivolts through 1000 volts ac



2022 NECA SAFETY PROFESSIONALS CONFERENCE

45

Phase Rotation Test Instruments

- Phase rotation instruments are commonly applied where modifications to electrical distribution systems are performed, such as the installation of a standby generator for an emergency or optional standby system
- Phase rotation is the order in which the voltage waveforms of a polyphase AC source reach their respective peaks
- This impacts the direction of a three-phase motor

2022 NECA SAFETY PROFESSIONALS CONFERENCE

46

Phase Rotation Test Instruments

- Phase rotation must be determined to ensure proper operation of three phase motor loads
- While contact type phase rotation devices are still in use, non-contact phase rotation instruments are readily available and significantly reduce the likelihood of an incident
- Contact type phase rotation instruments should be removed from service and replaced with noncontact devices

2022 NECA SAFETY PROFESSIONALS CONFERENCE



47

Phase Rotation Test Instruments

- Noncontact phase rotation instruments
- No exposed conductive parts
- Typically fit on insulated conductors up to 600 kcmil



2022 NECA SAFETY PROFESSIONALS CONFERENCE



48

Permanently Mounted Absence of Voltage Testers (AVT's)

- The general rule in NFPA 70E is that a qualified person, use an adequately rated portable test instrument to test each phase conductor or circuit part for the absence of voltage
- An exception to this rule prescriptively permits an adequately rated permanently mounted test device to test for the absence of voltage of the conductors or circuit parts at the work location, provided it meets the criteria provided
- An adequately rated permanently mounted test device (an AVT) is permitted to test for the absence of voltage of the conductors or circuit parts at the work location, provided it meets the following criteria:

2022 NECA SAFETY PROFESSIONALS CONFERENCE 

49

Permanently Mounted Absence of Voltage Testers (AVT's)

- An AVT is permitted to test for the absence of voltage at the work location, provided it meets the following criteria:
- (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 testing for 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

2022 NECA SAFETY PROFESSIONALS CONFERENCE 

50

Permanently Mounted Absence of Voltage Testers (AVT's)

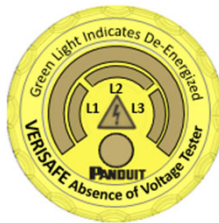


2022 NECA SAFETY PROFESSIONALS CONFERENCE



51

Permanently Mounted Absence of Voltage Testers (AVT's)



2022 NECA SAFETY PROFESSIONALS CONFERENCE



52

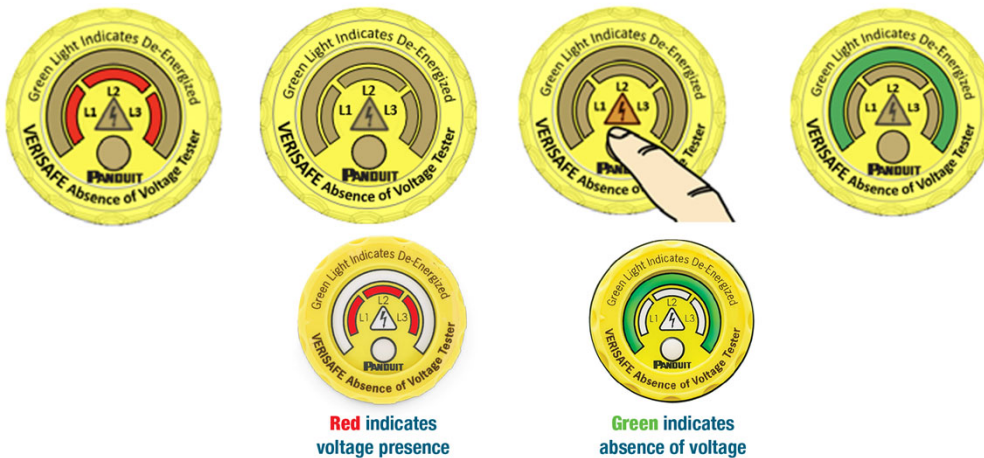
Permanently Mounted Absence of Voltage Testers (AVT's)



2022 NECA SAFETY PROFESSIONALS CONFERENCE

53

Permanently Mounted Absence of Voltage Testers (AVT's)



2022 NECA SAFETY PROFESSIONALS CONFERENCE

54

Permanently Mounted Absence of Voltage Testers (AVT's)

- It is extremely important to understand that only listed Absence of Voltage Testers (AVTs) meeting the requirements in NFPA 70E, are permitted to test for absence of voltage
- There are other permanently mounted devices that the electrical worker may encounter and must understand the differences between these devices and most importantly their limitations

2022 NECA SAFETY PROFESSIONALS CONFERENCE

55

Permanently Mounted Absence of Voltage Testers (AVT's)

- *Voltage Indicators, **not an AVT***
- These are permanently mounted devices that use an LED style indicators to illuminate when voltage is present
- These devices are not permitted to be used to test for the absence of voltage
- These devices are not self-monitoring, and are not a test instrument, they are used for indication only



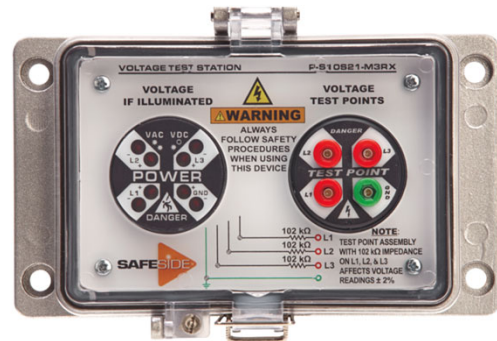
Voltage Indicator

2022 NECA SAFETY PROFESSIONALS CONFERENCE

56

Permanently Mounted Absence of Voltage Testers (AVT's)

- *Test Portals, **not** an AVT*
- Test portals are permanently mounted devices that can be used with a portable test instrument such as an electronic voltage tester or a digital multimeter
- Due to the high impedance introduced into the test portal limiting current flow to the test points to less than 5 milliamps, that a solenoid type voltage tester cannot be used on the test portal,



Test Portal

2022 NECA SAFETY PROFESSIONALS CONFERENCE

57

Questions????

- Thank You!

2022 NECA SAFETY PROFESSIONALS CONFERENCE

58

Complete the Online Evaluation



2022 NECA SAFETY PROFESSIONALS CONFERENCE

