Electrical measurement safety

Avoiding hidden hazards
Understanding safety standards
Goals of this education program

Goals:
• Awareness of electrical measurement hazards
• Understand safety specifications for digital multimeters (DMMs) and testers
• Understand the four installation measurement categories
• Minimize and avoid electrical measurement hazards

Outline:
• What electrical power can do to a DMM – and to you
• Common safety hazards
• Leading safety standards organizations
• NFPA and IEC safety standards
• Arc blast
• Meter safety inspection
• Meter safety checklist
Hidden danger: arc flash
What is an arc flash?

- Phase to phase or phase to ground short circuit
- Current passes through air. Ionized air (plasma) is a good conductor
- Duration of under one second
- Arc fault current is initially limited by the resistance (ohms) in the upstream wiring and transformers (less than an ohm on a 480 V ac circuit)
- Once an arc begins, it feeds off any matter in its path and vaporizes it
What can an arc flash do?

- Cause severe human and equipment damage
  - Frequently causes severe burns
  - Sometimes fatal
  - Almost always damages equipment
- Industry estimate
  - 5 to 10 arc flash incidents occur every day in the US
What can cause an arc flash?

**Short circuit**
- Racking a circuit breaker
  - Inserting or removing a breaker on a live bus
- Hand tool shorted across two phases
  - Experienced electrician cuts into live cable with cable shears, shear handle touches another phase
- Misuse of measurement tools
  - Measure across phases with an inline amp meter
  - Measure continuity on a live circuit with a tool that cannot withstand full voltage
  - Accidental shorting of phases with a test lead tip that is too long for the safety category

**High voltage transient**
- High voltage spike floating on line causes a spark / arc
Potential Hazards

1. Flashover inside meter
2. Fault current in test leads
3. Arcing at the terminals
4. Arc blast
Hidden danger: high voltage transients

- What can cause a spike?
  - Motor or other inductive load switching off
  - Equipment malfunction
  - Utility load switching
  - Adjustable speed drives
  - Lightning strike

- A spark can be created between two lines
- If the spark is on a high-energy line, all the current in the circuit can feed an arc

480 V rms, +/- 678 V peaks
Handheld test tool safety

How not to save time...

Last known earthly residence of automotive fuse used to replace original fuse

Test leads survived intact
Handheld test tool safety

The wrong meter to use on a power circuit

Probe tips burned off

250 V fuse didn’t open in time

Poor quality leads and probes led to injury
The electrician suffered severe burn injuries on his hand and arm.
Common errors with measurement tools

• Connecting a meter to a voltage source with the meter configured for inline amp measurements
  – Amps mode on meter is almost a short circuit
• Trying to measure ohms or continuity on a live circuit using the improper function
  – Some older meters cannot handle the full voltage on the ohms function
Misuse of DMM in ammeter mode
Who sets safety standards?

• **Occupational Safety and Health Administration (OSHA)**

• **National Fire Protection Association (NFPA)**
  – NFPA 70E (Standard for Electrical Safety in the Workplace)
  – NFPA 70 (National Electrical Code)

• **American National Standards Institute (ANSI)**
  – ANSI/ISA S82.02 (Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use)

• **Institute of Electrical and Electronics Engineers (IEEE)**
  – IEEE 1584™-2002 (Guide for Arc Flash Hazard Calculations)

• **International Electrotechnical Commission (IEC)**
  – IEC 61010 (same as ANSI/ISA S82.02 and Canadian Standards Association (CSA) C22.2 No. 1010.1-92)
  – IEC 61010-031:2008 “Safety requirements for handheld probe accessories”
Measurement categories

- The level and energy of voltage impulses are dependent on the location. The closer the location is to the utility supply, the higher the available fault current and the higher the category.

- IEC 61010 defines four locations or categories:
  
  **CAT IV**  “Origin of installation” – Utility level and any outside cable run fed by “mains” voltages, does not apply to low voltage communication cable
  
  **CAT III**  Distribution wiring, including “mains” bus, feeders and branch circuits; permanently installed loads
  
  **CAT II**  Receptacle outlet circuit, plug-in loads
  
  **CAT I**  Protected electronic circuits
Category locations
Measurement categories

Common sense ways to think of categories

• The higher the short circuit fault current available, the higher the category
  – High energy transients are much more dangerous, because they can trigger an arc blast

• The greater the source impedance, the lower the category
  – Transients are dampened by system impedance as they travel from the point where they were generated

• TVSS (transient voltage surge suppression) devices are larger (more joules) at the panel than at the receptacle outlet

• When you think about your measurement environment, also think about the hazard risk zones and PPE required as specified in NFPA70E
First the CAT, then the voltage

• Voltage rating by itself can be misleading
  – CAT III-1000 V (8 kV transient) is safer than CAT III-600 V (6k V transient)
  – But CAT III-600 V is safer than CAT II-1,000 V

• First know the category you are working in, then choose the appropriate voltage rating

• If you ever measure power circuits, you should use a CAT III-600 V or CAT IV 600 V/ CAT III-1,000 V meter
  – In addition to CAT IV 600 V/CAT III-1,000 V test leads and probes
Look for CAT III or CAT IV markings

CAT III-600 V
CAT III-1000 V
CAT IV-600V
CAT III-1000 V
CAT IV-600V
What about my old meter?

Meters and testers designed and produced before 1997 do not meet code.

Original
Fluke 70 Series

Not Rated

Older Fluke
70 Series-III
CAT II-600 V

Under Rated
National Fire Protection Association

NFPA 70E Standard for Electrical Safety in the Workplace:
Test instruments and accessories:

- Are part of personal protective equipment (PPE) (Article 250).
- Shall be rated for circuits and equipment to which they will be connected*
- Shall be designed for the environment to which they will be exposed, and the manner in which they will be used.*
- Shall be visually inspected before use on any shift. Defective or damaged equipment must be repaired and tested before being used again*
- The insulation of protective tools, including voltage test indicators, shall be verified by test and inspection (Article 250)

* NFPA 70E-2012 110.4(A)
NFPA 70E: Meters are part of PPE

• Your CAT-rated multimeter is part of your Personal Protective Equipment
• What is the difference between an NFPA 70E “Hazard/Risk” category and a CAT rating?
2012 edition of NFPA 70E

Important changes in the 2012 edition:

• More work is classified as Hazard/Risk (H/R) level 4, requiring full arc flash suit

• H/R level 1 now requires hearing protection

• Safety glasses are required by all four H/R levels

• Always wear arc-rated clothing

• Guidelines for thermographers are distinctly called out

• Includes guidelines for working with arc-resistant switchgear

• PPE and clothing requirements for each H/R level spelled out

• H/R level 2 now requires either a balaclava in combination with an arc-rated face shield, or an arc-rated flash suit hood
**Bottom line**

- If you work on three-phase circuits, you need a CAT III-600 V or CAT IV-600 V/ CAT III 1,000 V meter
- Look for the CAT rating and voltage rating marked near the input jacks
  - CAT or voltage rating alone can be misleading
- Look for independent certification
Bottom line

Safety must be built in

- An industrial grade meter devotes 10 to 15% of components exclusively to protection
- Built-in protection against the most common safety hazards:
  - High voltage transients and danger of arc-over
  - Voltage contact while in continuity or resistance mode
    - High integrity components
  - Voltage measurement while test leads are plugged into amps jacks
    - High energy fuses

Overload protection on all functions

1000 V high energy fuses

CAT IV-600 V
CAT III-1000 V
“Listed” vs. “designed to”

- IEC sets standards, but does not test or inspect for compliance
- A manufacturer can claim to “design to” a standard with no independent verification
- To be UL listed, or CSA or TUV certified, a manufacturer must employ the listing agency to test the product’s compliance with the standard
- Look for the listing agency’s emblem on the meter
Meter safety checklist

Watch for:
- Cracked or oily case
- Broken input jacks
- Bad test leads

No meter is safe when improperly used
- Use meters within their rating
- Use meters designed for measurements on power circuits
- Use only manufacturer-recommended replacement fuses
- Use test leads rated for the application; consider new test leads with less exposed metal
Safety inspection

Overload protection on volts inputs
With leads in V/Ω and COM inputs:
**Step 1:** Select VAC and put probes in a live outlet

Will you damage the meter if you...

**Step 2:** Select mV
**Step 3:** Select Ω

*Meter protection is designed for accidental misuse*
Safety inspection: fuse

Checking meter fuses on most Fluke meters

Step 1: Plug test lead in V/Ω input. Select Ω
Step 2: Insert probe tip into mA input. Read value
Step 3: Insert probe tip into A input. Read value

Is the fuse okay? What would an open fuse read?
Test lead safety checklist

Don’t let test leads be a weak point

• CAT III 1000 V or CAT IV 600 V/
  CAT III 1000 V rating
• Double insulation
• Wear indicator on lead wires
• Shrouded connectors
• Arc flash hazard consideration using
  specialized probes and PPE materials
• Finger guards
• Insulation not damaged (melted, cut,
  cracked or stretched)
• Connectors: no insulation pulled away
  from end connectors
• Probe tips: not loose or broken off (too short)
Safety inspection: lead resistance

Test leads and probes

Check test lead resistance:

Step 1: Insert leads in V/Ω and COM inputs

Step 2: Select Ω, touch probe tips (good leads are 0.1 to 0.3 Ω)

How do you check a single test lead?
Safety first

Safe practices include, but are not limited to, the following:

• Whenever possible, work on de-energized circuits.
  – Follow proper lock-out/tag-out procedures

• Use well maintained tools and appropriate personal protective equipment according to NFPA 70E
  – Safety glasses, insulated tools, insulating gloves, arc-rated clothing, arc shields, flash suits, insulating mats, etc.

• Don’t work alone

• Practice safe measurement techniques
  – Always connect the grounded lead first, hot second
  – Disconnect the hot lead first, grounded lead second

• Use the three-point test method
  – Test known circuit, measure target circuit, then re-test known circuit
Safety first

Planning for Safety

• Consider environmental concerns for your work and secure an Energized Electrical Work Permit
  – Additional Hazards
  – Operational Limitations
  – Clearance Required
  – Test Equipment Rating
  – Environmental Hazards
  – Lighting Condition
  – Ventilation
  – Qualified Helper
  – PPE Requirements
Common DMM / tester hazards

• Arc from transients (load switching spikes, lightning)
  Protection: Independent certification to meet CAT III-1,000 V or CAT IV 600 V

• Voltage contact while in continuity or resistance
  Protection: Overload protection in ohms up to the meter’s volt rating

• Measuring voltage with test leads in current jacks
  Protection: High energy fuses rated to the meter’s voltage rating
  Use meters / testers without current jacks

• Shock from accidental contact with live components
  Protection: Test leads double insulated, recessed / shrouded, finger guards, CAT III – 1,000 V. Replace when damaged

• Using meter or tester above rated voltage
  Protection: Good karma
Common DMM safety hazards

Three common avoidable errors

1. Measuring voltage while test leads are in the current jacks = short-circuit!
   **Protection:** Fluke meters use high energy fuses

2. Contact with ac or dc power source while in any mode other than ac/dc voltage
   **Protection:** Use a meter with “Overload Protection.”
   Functions are self-protected to the meter’s rated voltage

3. Using meter above its rated voltage, that is, on medium voltage circuits
   **Protection:** Good karma
Information

• Davis Instruments contact information
  – Tech Support/Product Quotations: 800-358-5525
  – Email: info@davis.com
  – Website: www.davis.com/fluke
Thank you for your time