Electrical Measurement Safety

Your right to be concerned

Risks from electrocution and shock hazards

Shock

- Contact with any source of electricity that causes a sufficient current through the skin, muscles, or hair.
- Shock can cause electrocution and death.

Current level	Probable effect on the human body
1mA	**Slight tingling sensation.** Still dangerous under certain conditions.
5 mA	**Slight shock felt; not painful but disturbing.** Average individual can let go. However, strong involuntary reactions to shocks in this range may lead to injuries.
6-16 mA	**Painful shock, begin to lose muscular control.** Possible fall danger. Referred to as the freezing current or "let-go" range.
17-99 mA	**Extreme pain, respiratory arrest, severe muscular contractions.** Individual cannot let go. Death is possible.
100-2000 mA	**Ventricular fibrillation (uneven, uncoordinated pumping of the heart.)** Muscular contraction and nerve damage begins to occur. Death is likely.
Over 2000 mA	**Cardiac Arrest, internal organ damage, and severe burns.** Death is probable.

Source: US OSHA, CDC, NIOSH

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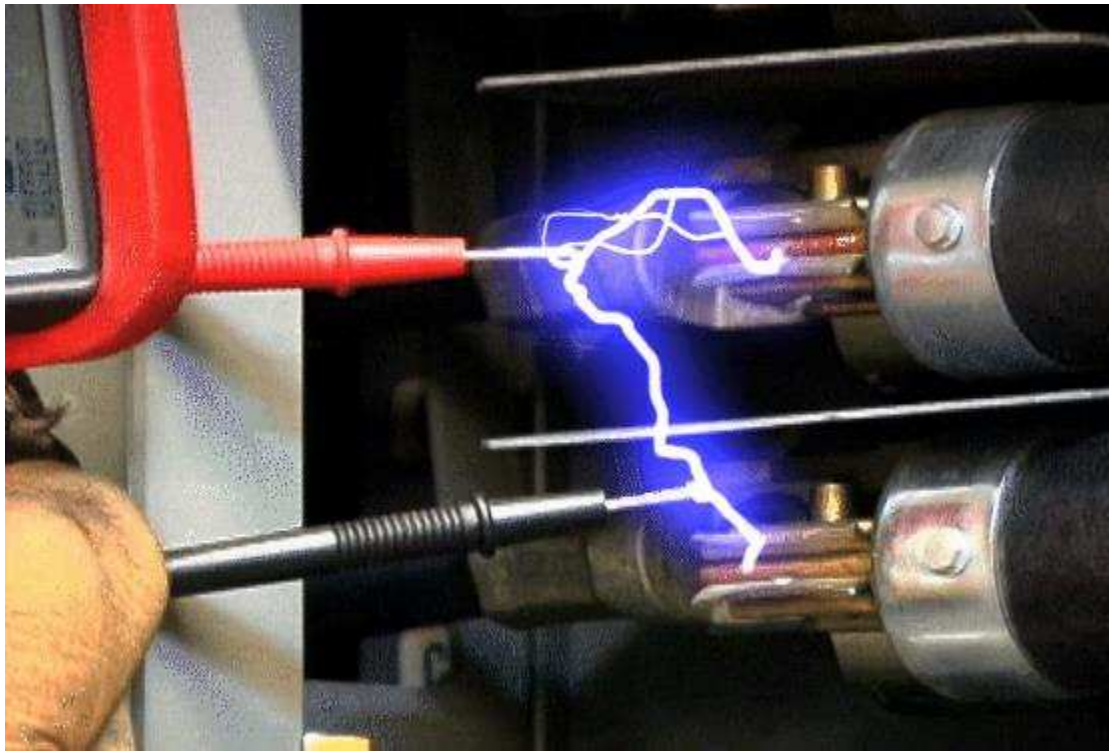
Risks from an arc flash

Created by a ***phase to phase*** or ***phase to ground*** short circuit.

- Current passes through the air.
- Ionized air (plasma) is a good conductor.
- Once an arc begins, it feeds off any matter in its path and vaporizes it.
- Duration is under one second.



Risks from an arc blast

The ***explosive*** result of an arcing fault.

- Vaporized conductors are rapidly expelled creating such hazards as intense heat, thermoacoustic shock wave, molten metal, shrapnel, blinding light, toxic smoke and contact with energized components.

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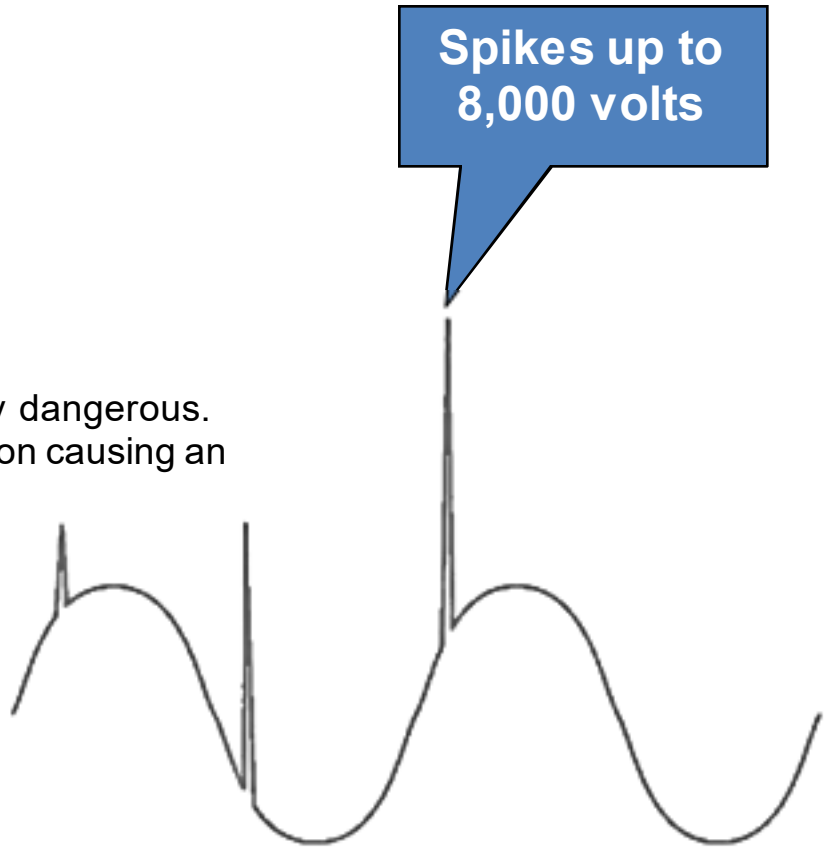
Transients can trigger an arc flash

What causes a transient?

- Motor or other inductive load switching off
- Equipment malfunction
- Utility load switching
- Adjustable speed drives
- Lightning strike

Transients:

- Are invisible and largely unavoidable.
- May last under 100 mS but can be extremely dangerous.
- May overcome test equipment input protection causing an arc/short in the tester.



Industry estimates

- 5 to 10 arc flash incidents occur every day in the US
- 77 % of recorded electrical injuries were due to arc flash incidents.
- Every year, more than 2,000 people are admitted to burn centers with severe arc-flash burns.

What likely causes these incidents?

1. Racking a circuit breaker
- Inserting or removing a breaker on a live bus.

2. Lose panel wiring
- A lose conductor that shorts across another conductor or ground.

3. Removing panel covers
- Retaining screws and fasteners fall into an unsecured panel against a live bus.

4. Hand tool shorted across two phases
- Experienced electrician cuts into live cable with cable shears, shear handle touches another phase.

5. Using incorrect test probes
- The user gets distracted or hand slips while measuring phase to phase or phase to ground while using old style ¾ inch probe tips.

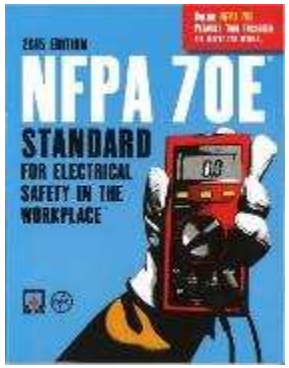
6. Misuse of measurement tools
- Measuring across phases with an inline amp meter creating a short circuit.
- Measuring continuity on a live circuit with a tool that cannot withstand full voltage.
- Accidental shorting of phases with a test lead tip that is too long for the safety category.

Follow industry guidelines

As the work environment and the type of job become more hazardous, the need for protection increases.

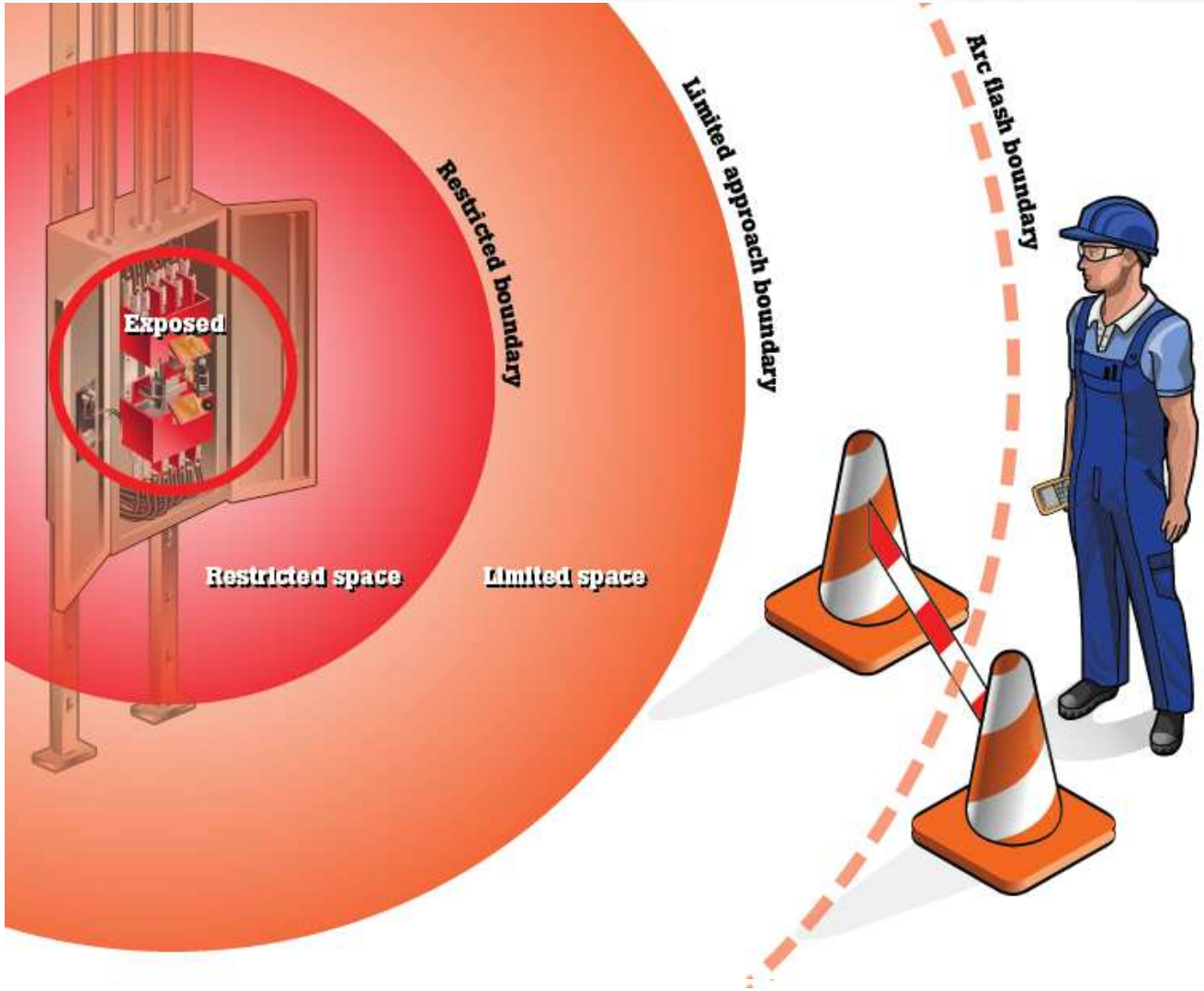
NFPA-70E[1] addresses:

- Safety-related work practices
- Maintenance of safety equipment
- Safety requirements for special equipment
- Safety related installation requirements



[1]**NFPA-70E** –
Standard for Electrical Safety in the Workplace

Safe working distances
Flash limits of approach



Boundaries apply when workers are exposed to energized electrical conductors or circuit parts.

PPE – Personal Protective Equipment

The PPE category is used to determine the necessary arc rating of a garment worn during a given job task.

PPE Category	Required Minimum Arc Rating of PPE	Typical Layers
1	4 Cal/cm²	1
2	8 Cal/cm²	1 or 2
3	25 Cal/cm²	2 or 3
4	40 Cal/cm²	3 or more

The higher the electrical environment, the stronger the personal protective equipment must be to withstand an arc-flash incident.

Images courtesy of Salisbury

Reduce the risk by using the right test equipment

NFPA: Test instruments are part of PPE (Article 110.4):

- 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. 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 110.4(5))

** NFPA 70E 110.4(A), 2015 Edition*

IEC 61010: International Standards for low voltage "test, measurement and control equipment"

Measurement Category locations or ratings

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 three measurement locations or categories:

CAT IV	Three-phase at utility connection, any outdoor mains conductor
CAT III	Three-phase distribution, including single-phase commercial lighting
CAT II	Single-phase receptacle connected loads

The greatest danger from transients is in the high categories, because they could trigger an arc blast.

Ensure your test equipment meets or exceeds industry standards

To provide better protection for electrical workers

standards have been developed for test equipment used in environments of 1000 volts or less, including 480 volt and 600 volt three-phase circuits.

IEC 61010 are the group standards for low voltage “test, measurement and control equipment”

First the category, then the voltage

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

- The working voltage could be 1,000 V, 600 V or 300 V
- Equipment can be dual rated, meeting both requirements
- If you measure power circuits, you should use a CAT III-600 V or CAT IV-600 V/CAT III-1000 V meter, in addition to CAT IV-600 V/CAT III-1000 V test leads and probes

Voltage rating by itself can be misleading

- CAT III-1000 V (withstands 8 kV transient) is safer than CAT III-600 V (withstands 6 kV transient)

Bottom line and most importantly,
know the measurement category and voltage you are working in.

Look for CAT markings between input jacks

The test equipment should be independently tested, marked and certified.

CAT III-600 V

CAT III-1000 V
CAT IV-600 V

CAT III-1000 V
CAT IV-600 V

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What if I can't find a rating?

Original
Fluke 70 Series

NOT RATED

***Old*er Fluke 70 Series-III**
CAT II-600 V

UNDER RATED

Meters and testers designed and produced prior to 1997
no longer meet code and therefore should be replaced.

Independent testing and certification

“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 TÜV 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.

Tester must be independently tested, marked and certified.

Read and understand the manufacturer's instructions

Non-contact voltage detectors

1. Verify the voltage detector function is working properly.
2. Make sure the detector is rated for the level of voltage being measured and is sensitive enough for your application.
3. Make sure that you also wear the appropriate PPE based on the environment you're in.
4. Make sure the hazardous voltage is not shielded.

Non-contact voltage detectors are a quick, inexpensive way to check for the **presence** of live voltage on ac circuits, switches and outlets before working on them.

Use only a digital multimeter or contact type voltage tester to test for the absence of voltage.

Live-dead-live testing

Verify the operation of the contact voltage tester

Before beginning the absence of voltage test, check the test instrument to ensure it is working properly in accordance with NFPA 70E Article 110.9 (A)(4)

1. Wearing proper PPE, measure a voltage similar to the voltage of the equipment about to be tested. This would include whether it is ac or dc and approximately the same magnitude.
2. Now test the circuit that is supposed to be de-energized.
3. Once testing is complete, re-verify the meter is still functioning properly by going to the same known voltage source and making another measurement.

Operational readiness test

Verify proper operation of test tools on a known voltage source before and after absence or presence of voltage testing is performed.

Several options:

1. Use a convenient electrical outlet (if available)
2. Access live conductors (posing unnecessary risk)
   – Suit up in appropriate PPE arc flash gear
3. No power exists

- The Fluke PRV240 Proving Unit provides a regulated and fixed ac or dc output voltage of 240 volts specifically to allow for verification testing of Multimeters, Clampmeters or testers

When test instruments are used for testing the absence of voltage on conductors or circuit parts operating at 50 volts or more, the operation of the test instrument shall be ***verified on a known voltage source*** before and after an absence of voltage test is performed.

NFPA70 E 2015 edition Article 110.4 (A)(5) Operation Verification proposed wording change

Test Lead Safety Checklist

Don't let test leads be a weak point!

Perform an inspection of the test leads

- ✓ CAT III-1000 V or CAT IV-600 V/CAT III-1000 V rating
- ✓ Wear indicator on lead wires
- ✓ Shrouded connectors
- ✓ 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)
- ✓ 4mm exposed probe tips in CAT III or CAT IV environments

Double insulation, finger guards, shrouds and recessed input jacks protect against electric shock from accidental contact with live circuits.

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Minimize exposed metal for safety

In accordance with IEC 61010-031
Safety requirements for hand-held probe assemblies for electrical measurement and test.

The amount of exposed metal at the tip of the test lead must match the energy potential of a given measurement

Other leads come with tip guards to minimize exposed metal

Some leads offer extendable tip shrouds to meet the reduced tip length requirement

The higher the CAT rating the less exposed metal is allowed at the tip of the test lead.

CAT II – 19 mm (0.75 inch)
CAT IV – 4 mm (0.16 inch)

The bottom line — Safety First

Best practices include:

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

2. **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.**

3. **Don't work alone.**

4. **Practice safe measurement techniques.**
   - **Always connect the grounded lead first, hot second**
   - **Disconnect the hot lead first, grounded lead second**

5. **Use the live-dead-live test method.**
   - **Test known circuit, measure target circuit, then re-test known circuit**

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Protection that's designed in

Built-in protection devices guard against the most common safety hazards:

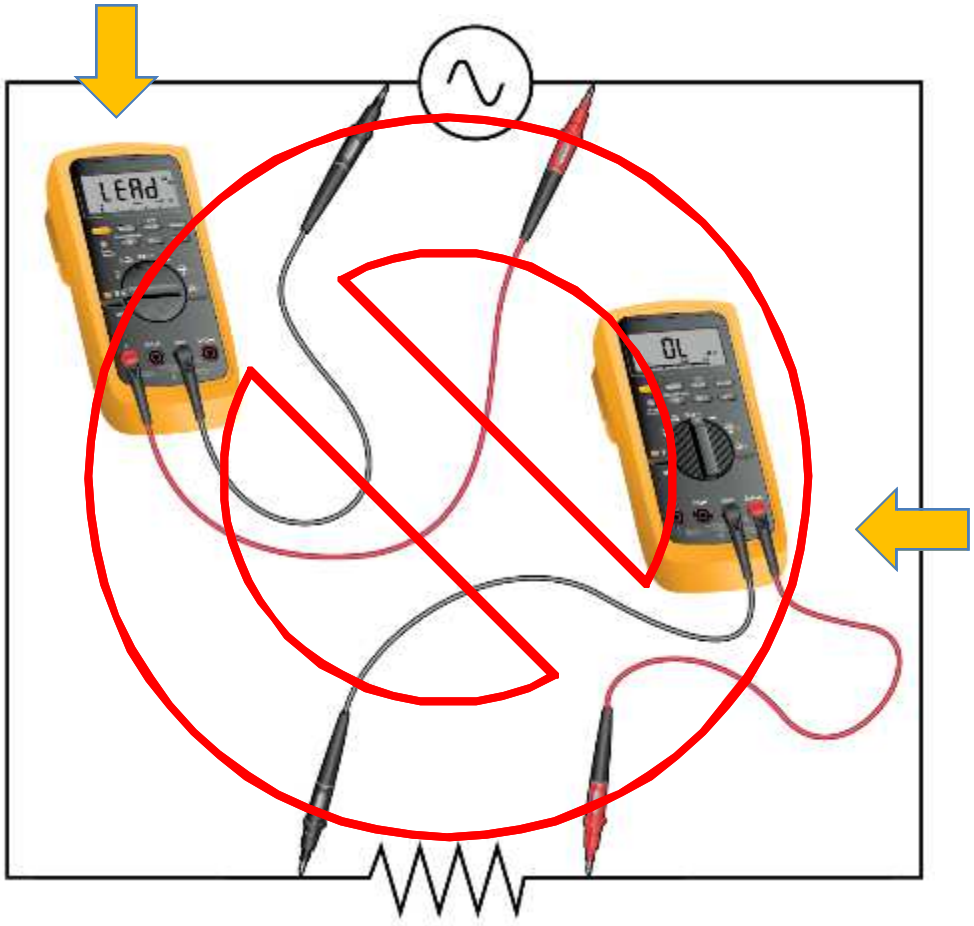
1. High voltage transients and danger of arc-over
2. Voltage contact while in continuity or resistance mode
3. Voltage measurement while test leads are plugged into the amps jacks

An industrial grade Fluke meter devotes 10 to 15% of its components exclusively to protection

Common errors with measurement tools

Connecting a meter to a voltage source with the meter configured for inline amp measurements.

The amps mode on a meter is almost a short circuit



Measuring ohms or continuity on a live circuit.

Most older meters cannot handle the full voltage on the ohms function