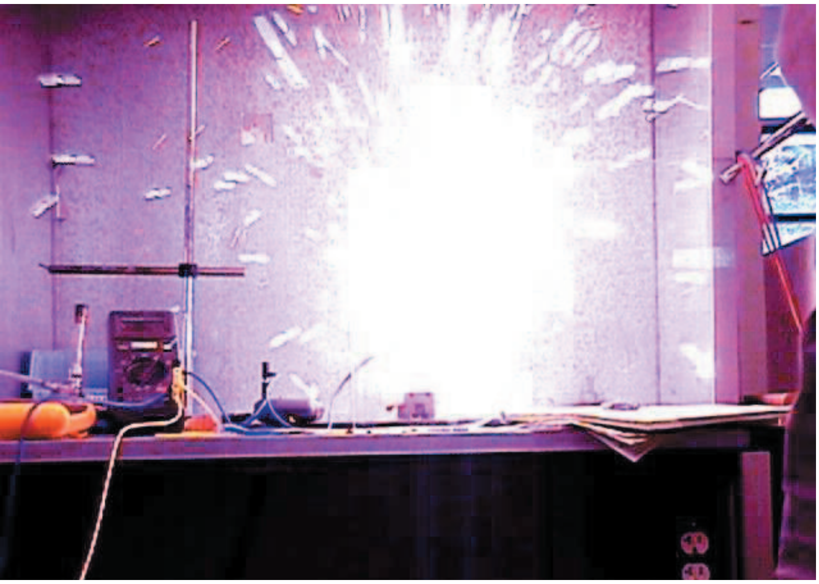
Testing live circuits safely

Application Note



Unsafe measurement practices can result in arc blasts like this.

Why do people show a profound interest in safety training after a fatality occurs? They respond this way because they have just had a point made very clear to them: the costs of working unsafely are high. While a fatality is tragic, the good news is you don't need to wait for one before learning how to work safely. Here, we'll look at some tips on doing just that, but we'll focus on testing live circuits. First, keep some key points in mind:

- Test equipment is safe only when you use it as intended.
- Using test equipment improperly may destroy the equipment under test and the test equipment, in addition to causing personal injury.
- Use only test equipment you have been trained to use. The amount of training you need depends on the test equipment and the test. In some cases, this means a few minutes of reading the instruction manual. In others, it means a formal class.

Regardless of what test equipment you use, certain safety principles apply. Let's take a look.

Prevention through inspection

Inspect test equipment before first use on a shift. If you see signs of damage, take it out of service until you've had it tested to insure it's safe to use. Remove grease or other contaminants that can compromise the integrity of the insulation.

Check the voltage rating, current rating and measurement category rating of the test instrument to verify it is correct for your testing environment. Do not count on fuses or test lead insulation to protect you from misuse. Measure a live circuit or circuits to insure the test equipment is in working order. Count on proper training and the right test equipment to protect you from misuse.

Inspect test leads for signs of damaged insulation, and check internal fuses in your test equipment and replace any damaged items before proceeding.

Inspect the equipment to be tested. Insure you can test without interfering in operations or operating something that may create a hazard for you or someone else. Coordinate this with other groups, such as operations or other trades. Follow lockout/tagout rules, and insure everyone working around the same equipment is also following them. Look for hazardous conditions, such as missing covers, exposed wiring or bus, and National Electrical Code violations.

Inspect the work area. Look for falling hazards, tripping hazards, fire hazards, and other unsafe conditions. Correct these before doing the work.

Make sure you have the proper PPE for the task at hand

Inspect your Personal Protective Equipment (PPE) before performing the task. Is it rated for the voltage and energy under test? Are you protecting each body zone, such as head, eyes, ears, trunk, arms, fingers, and legs? Is your PPE in good condition? Are you using it correctly? Do you have sufficient PPE to prevent injury? Ask "what if" questions, and determine what PPE you need to protect yourself — maybe safety glasses, gloves, face shield, insulating blankets, or even a flash suit. Each situation is different, even on similar equipment. If you are not sure of the proper PPE requirements for your application, consult the most recent editions to NFPA 70 E and NEC (Article 110.16) related to protective equipment and flash protection and be knowledgeable of local regional code requirements. Additionally, outside the U.S., consult the relevant international standards.

Inspect the test setup before making connections.

Safe connections

Kirchoff's Law is an important one to remember when working around electricity. Essentially, it says electricity will flow proportionately through all paths presented to it. When making connections, don't provide electricity with a complete path across your heart. In other words, place one hand behind your back and connect one test lead at a time. Preventing electrocution isn't the only benefit of using this method, as opposed to holding one lead in each hand. Simultaneous connection or disconnection of test probes can create a path of ionized particles between the probes if the operator were to slip and draw an arc. This, in essence, is a parallel path between ground and the energized circuit or between different phases in the panel under test. If you are thinking, "But, isn't that a fault condition?" you are right. And a fault condition can result in an arc blast. Therefore, make or break test connections one at a time.

Determine the safest place to make the connection, and the safest place to stand when you make it. Whenever possible, measure on the load side of a protective device (such as a fuse that carries the least load or the lowest rating). Make sure you have safe access and stand with your body shielded by a panel cover. If you are measuring voltage with respect to ground, make the ground connection first then connect to the hot side. When finished, remove the hot connection first and the ground connection last. If you need to measure ohms, check the test points for voltage first.

If you are using alligator clips, don't try to grab a screw head unless you are using a clip specifically designed to grasp a screw head like the SureGrip AC220 from Fluke. Look instead for a good connection such as short piece of bare wire or threaded stud where you know the clip will stay connected and has proper spacing to prevent inadvertent shorting to another location. Be aware that the open jaws of an alligator clip can short across adjacent parts.

A measurement example

Suppose you need to measure voltage in a service panel. The safety procedure begins before you do the measuring. Ensure you have the right PPE and tools. Inspect your meter and your leads. Insure that the meter and leads are in good condition and that they both are appropriate, both in voltage rating and measurement category, for the task at hand. If the meter has a fused current range, check the fuses (See Figure 1).

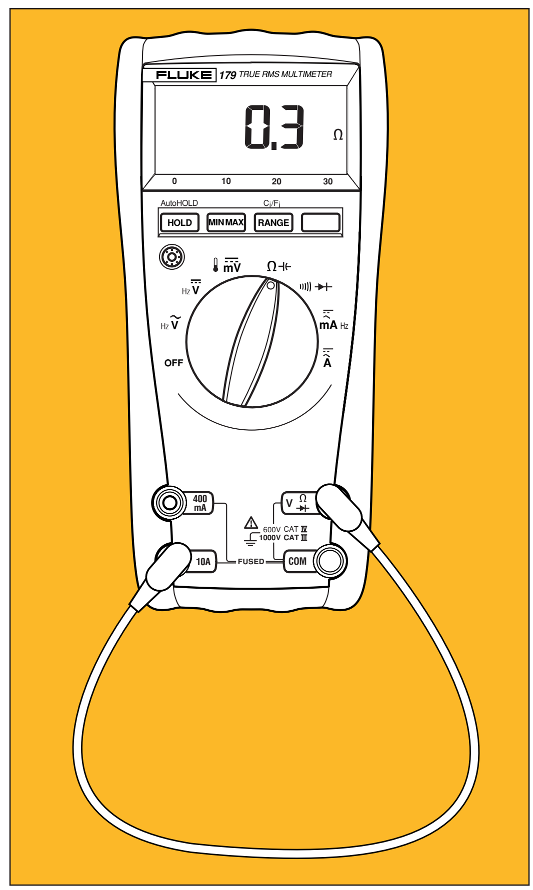


Figure 1. To check the fuses on most meters plug a test lead in V/ ohm (Ω) input and select ohms. Next insert the probe tip into mA input and read the value. 2.0 ohms is typical. Next, insert the probe tip into A input and read the value. 0.5 ohms is typical.
(Note that this test does not test for the wrong fuse being installed, as could happen if the original fuse was replaced with a low energy fuse.)

As you approach the panel, inspect the surrounding area. Look for the hazards mentioned earlier, and eliminate or minimize them before proceeding. Also, look for escape routes and fire safety equipment. Where are the emergency exits and fire extinguishers? Then, inspect the equipment. Be sure to look inside the panel for any damaged insulation or loose wires that could cause a problem while your hands are in there.

Find a safe place at which to make your measurement connection. Here, it might be the load-side of a 200 A breaker in a panel of various breakers rated from 200 A to 800 A. But, suppose getting at the terminals requires reaching through a bundle of wiring or reaching around a busbar, when a 400 A breaker is very easy to reach and its terminals are out in the open. The 400 A breaker would be your logical choice. Similarly, if you must remove a panel cover or expose yourself to several other breakers to get at a given breaker when another is easily accessible, the choice is obvious.

Unattended monitoring

Secure test equipment in a way that prevents damage, tampering, or theft. Route test leads to eliminate pinching or other kinds of damage. Keep the system as closed as possible — put panel covers, doors, and guards back in place as much as possible. Place barriers, such as safety tape, around energized equipment under test. Post an information sheet or card in an accessible and visible spot near the equipment under test, so others can see what is going on.

Be vigilant

One of the biggest dangers you will ever face is your own complacency. Don't fall into the trap of considering any measurement to be routine just because you have done it many times before. Circumstances change, and only constant attention to safety will allow you to adapt to them. If you don't already have a safety checklist, consider making one. Pilots go over the same preflight checklist, no matter how many flights they have made. You should review the same testing safety steps, no matter how many tests you have done.

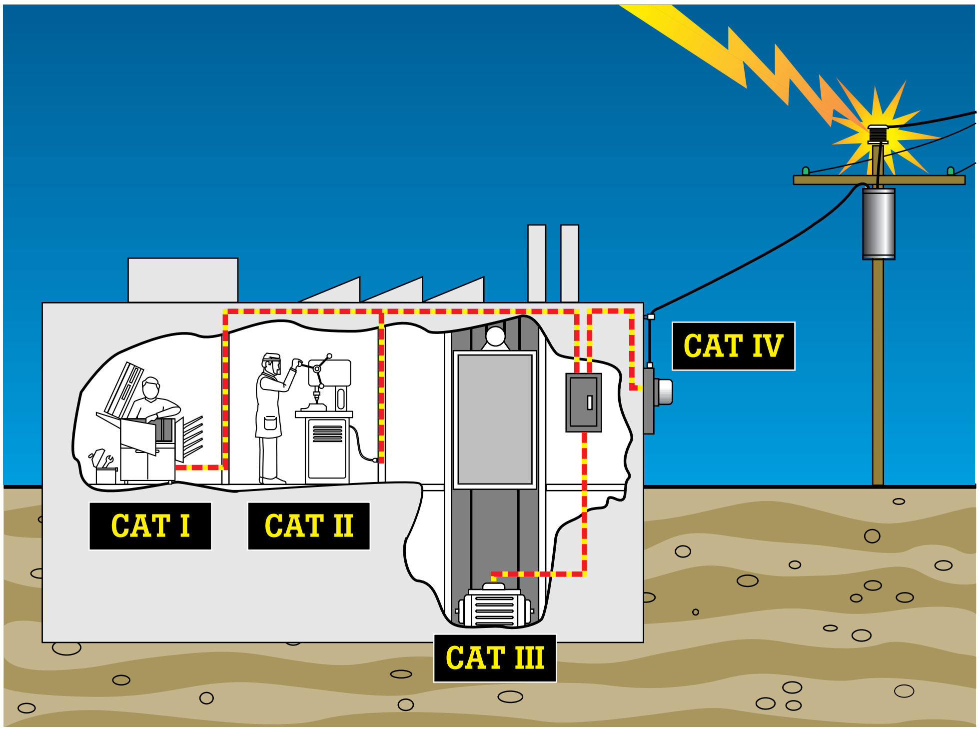
Many of us are hesitant to speak up when a coworker is doing an unsafe act. Don't hesitate. If, for example, a coworker has a probe in each hand and begins moving those hands toward an energized circuit, you are both at risk. If a coworker stops you from engaging in an unsafe act, consider that an act of professional courtesy.

Some safety standards

The following safety standards apply to electrical testing:

- OSHA 1910, Subpart S
- OSHA 1926, Subparts V and K
- NFPA 70E, Standard for Electrical Safety Requirements for Employee Workplaces (available from NFPA 1-800-344-3555)
- ANSI/ISA - S82.01 (IEC-1010-1) Safety Standard for Electrical and Electronic Test, Measuring, Controlling, and Related Equipment (Related application note and video available from Fluke Corporation 1-800-443-5853)
- ANSI Z89.1, Requirements for Protective Headwear for Industrial Workers
- ANSI Z87.1, Practice for Occupational and Educational Eye and Face Protection
- ASTM D120, Specification for Rubber Insulating Gloves
- ASTM D178, Specifications for Rubber Insulating Matting
- ASTM F1506, Standard Specification for Protective Wearing Apparel

Understanding safety categories



Overvoltage category	In brief	Examples
CAT IV	Three-phase at utility connection, any outdoor conductors	• Refers to the "origin of installation"; i.e., where low-voltage connection is made to utility power. • Electricity meters, primary overcurrent protection equipment. • Outside and service entrance, service drop from pole to building, run between meter and panel. • Overhead line to detached building, underground line to well pump.
CAT III	Three-phase distribution, including single-phase commercial lighting	• Equipment in fixed installations, such as switchgear and polyphase motors. • Bus and feeder in industrial plants. • Feeders and short branch circuits, distribution panel devices. • Lighting systems in larger buildings. • Appliance outlets with short connections to service entrance.

CAT II	Single-phase receptacle connected loads	• Appliance, portable tools, and other household and similar loads.
		• Outlet and long branch circuits.
		  • Outlets at more than 10 meters (30 feet) from CAT III source.
		  • Outlets at more that 20 meters (60 feet) from CAT IV source.

CAT I	Electronic	• Protected electronic equipment. • Equipment connected to (source) circuits in which measures are taken to limit transient overvoltages to an appropriately low level. • Any high-voltage, low-energy source derived from a high-winding resistance transformer, such as the high-voltage section of a copier.

Overvoltage installation categories. IEC 1010 applies to *low-voltage* (< 1000 V) test equipment.

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