Think 'Test Instruments' when you think of personal protective equipment (PPE)

Application Note

Gloves, glasses, flame-resistant clothing — this Personal Protective Equipment (PPE) is all familiar and important to those of us who work with electricity. But here's a thought that may surprise you.

When you think about the vital protective equipment that helps ensure your safety, don't forget to include your first line of defense: your test instruments and test leads.

Who says so? No less an authority than the National Fire Protection Association (NFPA). The NFPA considers test instruments and their associated equipment to be an integral part of the PPE electrical system professionals must use on the job.

According to the NFPA, "test instruments, equipment, and their accessories shall be designed for the circuits and equipment they'll be connected to, and the environment where they'll be used."[i] Sounds like common sense. And like most common sense advice, there are solid reasons behind it.

Hazards of electrical test measurement

Any work near live electrical circuits poses its share of risk, and electrical measurement jobs are no exception. In commercial and industrial settings today, electricians commonly work with high-energy circuits up to 480 volts. In Canada, circuits up to 660 volts are used. Though they are officially classed as "low voltage," these powerful circuits can deliver a deadly punch.

In addition to the danger of electrical shock, such circuits have enough power available to fuel an electric arc explosion, which can generate the searing heat called arc flash and the noise and pressure wave caused by arc blast.

Arc flashes occur an estimated 5 to 10 times each day in the US, costing 200 to 300 lives a year. When arc flash occurs, personal protective equipment is the only thing that can defend the electrician from horrific injury, pain and even death.

The danger of voltage transients

The presence of voltage kickback spikes, called transients, is a characteristic of electrical supply systems that creates important safety implications. When transients occur while a person is taking electrical measurements, they can lead to an arc explosion.

Transients are present in almost every electrical supply system. In industrial settings they may be caused by the switching of inductive loads and by lightning strikes. Though such transients may last only milliseconds, they may carry thousands of amps of energy. For anyone taking measurements on electrical equipment, the consequences can be devastating.

When such spikes occur while measurements are being made, they can cause a plasma arc to form — inside the measurement tool, or in the air outside. The high fault current available in 480-volt and 660-volt systems can generate an extremely hazardous arc flash.

Understanding arc flash

How can such a problem develop? A transient of sufficient magnitude can cause an arc to form between conductors within an instrument, or across test leads. Once an arc occurs, the total available fault current can feed the arc and cause an explosion.

The result is an arc flash, which can cause a plasma fireball fueled by the energy in the electrical system. Temperatures can reach about 6,000 degrees Celsius, or 10,000 degrees Fahrenheit. The arc can cause a sonic and pressure wave capable of spraying a bystander with molten metal, knocking them to the ground and damaging their hearing.

Transients are not the only source of arc-flash hazard. A very common misuse of hand held multimeters can trigger a similar chain of events.

If the multimeter user leaves the test leads in the amps input terminals and connects the meter leads across a voltage source, that user has just created a short through the meter. While the voltage terminals have a high impedance, the amps terminals have a very low impedance. This is why a meter's amps circuit must be protected with fuses.

Another common and dangerous misuse of test equipment is measuring ohms or continuity on a live circuit. These measurements should be made only on circuits that are not energized.

PPE to the rescue

Standards organizations such as the American National Standards Institute (ANSI) and American Society for Testing and Materials (ASTM) have developed detailed requirements and specifications for such protective equipment as eye and hearing protection, insulated hand tools, insulated gloves and fire resistant clothing. NFPA standard 70E provides detailed guidelines about when and where this approved safety equipment should be used. NEC (National Electrical Code) Article 110.16 further defines PPE. Also be aware of possible additional local government and country requirements.

As an integral component of PPE, test tools and equipment must also meet safety requirements. These standards are established by such organizations as ANSI, the Canadian Standards Association (CSA), and the International Electro-Technical Commission (IEC). Together they have created stringent standards for voltage test equipment used in environments up to 1000 volts.[1]

ANSI, CSA and IEC define four categories of over-voltage transient impulses. The rule of thumb is that the closer the technician is working to the power source, the greater the danger and the higher the measurement category number. Lower category installations usually have greater impedance, which dampens transients and helps limit the fault current that can feed an arc.

- CAT IV is associated with the origin of installation. This refers to power lines at the utility connection, but also includes any overhead and underground outside cable runs, since both may be affected by lightning.
- CAT III covers distribution level wiring. This includes 480-volt and 660-volt circuits such as 3-phase bus and feeder circuits, motor control centers, load centers and distribution panels. Permanently installed loads are also classed as CAT III. CAT III includes large loads that can generate their own transients. At this level, the trend to using higher voltage levels in modern buildings has increased the potential hazards.
- CAT II covers the receptacle circuit level and plug-in loads.
- CAT I refers to protected electronic circuits.

It is important to note that CAT ratings as marked on test and measurement equipment have no relation to the PPE category listing of zero to four (0-4) for personnel protective clothing as determined by surface energy level (cal/cm^2) according to NFPA 70E.

Safety standards for measurement tools

As safety standards add requirements and improve definitions for today's environments, they also render many older test tools obsolete. Yesterday's tools just don't meet contemporary standards for insulation, impulse protection from transient voltage spikes and excessive voltage misuse (through internal design and proper fusing), and effective single fault protection.

Ask yourself whether your test tools meet today's tough standards. Here's what to look for:

Beware of vintage tools — Old test instruments, while they may be perfectly accurate and appear to perform well, may not meet today's safety requirements. Even the best meters of yesterday were designed for a world where working conditions and safety standards were far different. Such test tools may not meet contemporary standards and should be replaced.

Demand independent testing and certification — Even in the vital area of safety, some tools may not deliver the performance promised by the manufacturer. Measuring devices rated for a high-energy environment may not actually deliver the safety protections, such as adequate fusing, claimed on their specification sheets.

It is important to understand that standards bodies such as ANSI, CSA and IEC are not responsible for enforcing their standards. A meter *designed* to a standard may not have been actually *tested* and proven to meet that standard. It is not uncommon for meters under test to fail before achieving the performance their manufacturers claim for them.

Your best protection is to choose test instruments that have been *tested* and *certified* to perform up to specification by independent testing laboratories, such as Underwriters Laboratories (UL) in the United States, Canadian Standards Association (CSA) in Canada and TUV Product Service in Europe.[ii] For greatest safety, select test tools certified to meet the appropriate contemporary standards by two or more independent labs. This ensures that testers have passed the most rigorous tests and meet every applicable standard.

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See for yourself: Test tool inspection and maintenance

Mandated regular inspection and maintenance — Like all PPE, test tools must be regularly inspected and maintained. NFPA Standard 70E lays out the requirement that test tools must be visually inspected frequently to help detect damage and ensure proper operation. Part II, Chapter 4, Paragraph 4-1.1 makes it clear:

> **Visual inspection.** Test instruments and equipment and all associated test leads, cables, power cords, probes, and connectors shall be visually inspected for external defects and damage before the equipment is used on any shift. If there is a defect or evidence of damage that might expose an employee to injury, the defective or damaged item shall be removed from service, and no employee shall use it until repairs and tests necessary to render the equipment safe have been made.[iii]

This inspection alone, however, may not detect all possible test instrument problems. To help ensure the highest level of safety and performance, you need to conduct additional inspection and testing. After all, it's your safety at stake:

Additional visual inspection — Test tools should be checked for the following points:

- Look for the 1000-volt, CAT III or 600-volt, CAT IV rating on the front of meters and testers, and a "double insulated" symbol on the back.
- Look for approval symbols from two or more independent testing agencies, such as UL, CSA, CE or TUV.
- Make sure that the amperage and voltage of meter fuses is correct. Fuse voltage must be as high or higher than the meter's voltage rating and able to support the full surge current of the maximum listed voltage in the voltage input terminals. The second edition of IEC/ANSI/ CSA standards states that test equipment must perform properly in the presence of impulses on volts and amps measurement functions. Ohms and continuity functions are required to handle the full meter voltage rating without becoming a hazard.
- Check the instrument's manual to verify that the ohms and continuity circuit is protected to the same level as the voltage test circuit. If the manual does not include that information, your supplier should be able to determine whether the meter complies with IEC61010 2nd edition or ANSI S82.02.
- Check the overall condition of the meter or tester. Look for such problems as a broken case, worn test leads or a faded display.

Use the meter's own test capability to determine whether fuses are in place and functioning properly.

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.

Inspecting test leads and probes — As integral components of the test tool system, test leads, probes and attachments must meet the requirements of the testing environment and be designed to minimize hazard. Test leads must be certified to a category that equals or exceeds that of the meter or tester.

- Examine test leads for such features as shrouded connectors, finger guards, CAT ratings that equal or exceed those of the meter, and double insulation.
- Visually inspect for frayed or broken wires. The length of exposed metal on test probe tips should be minimal.

Test leads can fail internally, creating a hazard that cannot be detected through visual inspection. But it is possible to use the meter's own continuity testing function to check for internal breaks. 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 - 0.3 Ω.

Conclusion

By treating your test tools like the vital items of personal protective equipment they are, you can help protect yourself from the extremely hazardous conditions of arc flash and arc blast. Select these tools carefully. Choose the very latest and best, the tools that meet the highest performance standards. Then inspect and test them rigorously.

You are a professional. Your customers expect a lot from you, and you deliver. If you demand the same from your test tools, they will deliver too — and keep you safe.

1 The pertinent standards include ANSI S82.02, CSA 22.2-1010.1 and IEC 61010. These standards cover systems of 1000 volts or less, including 480-volt and 660-volt, three-phase circuits. For the first time, these standards differentiate the transient hazard by location and potential for harm, as well as the voltage level.

i NFPA 70E "Standard for Electrical Safety Requirements for Employee Workplaces, 2000 Edition, Chapter 3, Section 3-4.10.

ii For more information on these testing organizations, visit their websites:
http://www.ul.com/
http://www.csa.ca/Default.asp?language=English
http://www.tuvamerica.com/services/electrical/lowvolt.cfm

iii NFPA 70E Standard for Electrical Safety Requirements for Employee Workplaces, 2000 Edition, page 63. ©2000 NFPA

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